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History of Science, Philosophy and Culture
in Indian Civilization

General Editor D.P. Chattopadhyaya

Volume III Part 1

History of Indian Science, Technology and Culture

AD 1000-1800

edited by
A. RAHMAN

PHISPC

The volumes of the PROJECT ON THE HISTORY OF SCIENCE, PHILOSOPHY AND CULTURE IN INDIAN CIVILIZATION aim at discovering the main aspects of India's heritage and present them in an interrelated way. These volumes, in spite of their unitary look, recognise the difference between the areas of material civilization and those of ideational culture. The Project is not being executed by a single group of thinkers and writers who are methodologically uniform or ideologically identical in their commitments. In fact contributions are made by different scholars with different ideological persuasions and methodological approaches. The Project is marked by what may be called 'methodological pluralism'.

In spite of its primary historical character, this Project, both in its conceptualization and execution, has been shaped by many scholars drawn from different disciplines. It is for the first time that an endeavour of such a unique and comprehensive character has been undertaken to study critically a major world civilization like India.

This volume deals with studies on science, technology and culture in India from tenth to eighteenth century. The nine centuries of India's history covered here has, until recently, been seen as a 'dark age' in the development of science in the country. But it was a period of intense debate and advancement in different fields including science, enriched by the impact of Arabic and Persian scholars into India during which many of the key principles of modern-day scientific thinking were established.

The volume brings together some of today's leading scholars from different disciplines to explore the development of science and technology, and their impact in the growth of social and religious lives of the people in this country. The essays address such diverse topics as: food, agriculture, metallurgy, mathematics, astronomy, chemistry and alchemy, irrigation, paper technology, science and social movements. In addition, there are studies on the impact of Bhakti and Sufi movements on the lives of women of this period.

For those interested in science and technology, and their impact on social lives, this will be an essential book.

History of Indian Science, Philosophy and Culture AD 1000-1800

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Foreword

That India has a rich philosophical and religious heritage to its credit is generally recognized. Of its scientific and technological tradition, the Euro-American world of learning seems to be sadly unaware. Informed opinions have been expressed to the effect that India, unlike some other ancient civilizations, has not suffered any breakdown and undergone the resulting discontinuity. The historians and ideologues of the colonial powers hardly took the pains to look into the factors which could plausibly account for the continuity of the civilization despite its numerous military defeats. Exaggerated and coloured attention paid to the political and military affairs and systematic indifference to the techno-economic traits of the social organization yielded a distorted tapestry of Indian history. The effect of distortion gets magnified because of the misplaced emphasis laid on the religious factors disregarding their social roots and embroidering their conflicting fallout. Attempts to understand and reconstruct the history of science and technology of medieval India by trying to relate it with the 'rise' and 'fall' of Hinduism, Buddhism and Islam are fated to reap poor historical harvest unless it is firmly kept in view that the values of the religious variables are themselves substantially social.

Much of the problematical issues attending the reconstruction of the history of medieval India disappears or thins down provided the working historians succeed in freeing their mind from the myth of 'Dark Age' associated with the effective presence of Islam in northern India. Understandably the indigenous forces which had been at work in India before the arrival of the Muslim rulers did not suddenly disappear after their settlement mainly in towns and cantonments. The ways of life of the rulers could not supplant overnight those of the numerically superior ruled spread over the length and breadth of the country. Ruling does not mean a simple process of military conquest followed up by imported forms of administration. It is a much more complex and long-durational process of adjustment, accommodation, conflict, strife and reconciliation at the ground level. This involves many-sided give-and-take—linguistic, institutional, legal and religious, scientific and technological, artistic and architectural, in brief, substructural, midstructural and superstructural. The elements and perspectives of acculturation, historical analysis reveals, are cybernetically related.

Every cultural group has its own way of classifying or categorizing the objects of its experience, natural and otherwise. Shaped by the forces of nature and as part of nature itself humans are objectively obliged to grapple, both theoretically and practically, with the problems posed by nature. The discovery of the laws of nature and the invention of the techniques to define human relations with environment are the evolutionary outcomes. If nature and whatever evolves out of it are studied under science or epistemology, the possible ways of transforming nature into cultural forms are found in arts, artefacts and technology.

If the variations due to environmental difference are duly discounted, the general features of the recorded history of science and technology of different civilizations exhibit striking similarity. For example, the types of diseases and their possible cures can be profitably understood in terms of the concerned climatic conditions, vegetation patterns and the available minerals and alchemic practices in the area. Similarly, the forms of human habitation and transport are understandably influenced by the geographical configurations of plains, mountain ranges, river systems and proximity to or distance from ocean and desert. If desert and drought conditions tend to make human groups nomadic or keep them on constant move, fertile river basins extend invitation for their settlement. For the related purposes—movement, settlement, transport and food production, knowledge and use of forestry, metallurgy, animal husbandry, agriculture and irrigation are obviously necessary. Through experience and cultural borrowing, knowledge and skill in these areas keep on changing and improving over the centuries. By the beginning of the eleventh century AD the indigenous tradition of science and technology in India, partly due to internal motive-force and partly due to cultural borrowing, reached a fairly high level in certain areas like astronomy, metallurgy, medicine and agriculture.

At the same time, signs of decline and exhaustion started becoming evident in certain other areas like navigation and military science. Loss of control over the waters of Indian Ocean had an obvious negative impact not only on the political fortunes of India but also on its possible scientific development. Relative insularity, loss of interest in keeping records of their observed data, social rigidity and the resulting lack of professional mobility, inadequate royal patronage for scientific research and the speculative orientation of the best minds are among the factors to be held responsible for the decline of science in the medieval India. However, it would be wrong to think that no progress was made in any domain of *epistémé* and *techné*, science and technology. In the fields of philosophy, religion, fine arts, architecture and town planning some works of lasting significance were done. Because of the relative non-availability of productive surplus for investible purpose and archaic land revenue system, coupled with the absence of the spread of public education, economic growth could not achieve a high level. The dominance of the oral tradition, in spite of its positive aspect, had its obvious limits.

Professor A. Rahman and his colleagues present an excellent bouquet of learned papers on the History of Science of India spanning from the eleventh to eighteenth centuries, from the effective presence of the Muslim rulers in North India to the establishment of British rule in the East India. The commendable scholarship of the contributors and the imaginative editorial planning of the volume have added much to its individual worth. The reader would be happy to note that the perception of different writers, their emphasis, formulations and conclusions are not mechanically uniform. On the same themes and problems the different suggestions and hypotheses which stem from the editorial policy and contributors' freedom are expected to trigger off critical research and creative controversy.

Speaking at a relatively abstract level it may be pointed out that contributions to the volume judiciously blend and comprise such highly theoretical ideas of space, time and mathematics and practical aspects of life like rituals, agriculture and food. Perceptive attention has been paid to the changing interaction between different philosophical and religious movements in general and science and technology in particular. One of the most rewarding features of the volume seems to be the writers' conscious intention to situate their problems and themes of study in the appropriate social contexts. In other words, the writers' attempt to show that cognitive enterprises and technological innovations are not to be understood in *vacuo* and, positively speaking, have to be traced to their cultural matrix has made this volume so profitably readable. It has imparted the much-solicited concrete character to the history of medieval India.

D.P. CHATTOPADHYAYA
General Editor and Project Director

Contributors

Wazir Hasan Abdi has taught mathematics for more than four decades in different universities and institutions in India and abroad. He has authored many papers on mathematics and history of Indian science.

K.T. Achaya's interest lie in the areas of dairy products, oilseeds and oils and nutrition, in which he has published numerous research papers and several books. His studies have resulted in books on oilseeds and technology and on the colourful mosaic of Indian food.

Arun Kumar Biswas taught mineral engineering and metallurgy at the Indian Institute of Technology, Kanpur (1963-95) and is at present Professor of History of Science at the Asiatic Society, Calcutta. Professor Biswas is a renowned scholar in the areas of mineral engineering, archaeo-metallurgy, Ramakrishna-Vivekananda Literature and History of Science. Among his more than hundred papers are twelve publications on Science in India and recent two volumes Minerals and Metals in Ancient India (1996), both highly acclaimed by critics.

Vijaya Jayant Deshpande, received a Doctorate in History of Science from the Punjab University in 1989. Her fields of interest are history of alchemy, chemistry and medicine, especially transmission of ideas between India and China. She worked as a research associate of Indian National Science Academy at the Bhandarkar Oriental Research Institute, Pune where she carried out a critical study of the Sanskrit alchemical text *Rasopanishad.* In 1994-5 she was at the Beijing University as a post-doctoral fellow in India-China Cultural Exchange Programme. Presently she is a Wellcome Fellow for the History of Medicine at the School of Oriental and African Studies, London. Her articles are published in various journals including the *Indian Journal of History of Science.*

Lallanji Gopal was formerly Director of Advanced Centre in Philosophy, Head, Department of Indian Philosophy and Religion, Sayajirao Gaekwad Professor of Indian Culture and Civilization and Professor of Ancient Indian History, Culture and Archaeology. He has written and edited more than twenty books and articles.

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A. Rahman is the editor of the present volume. He was the first Director of National Institute of Science, Technology and Development Studies (NISTADS), New Delhi. Pioneer in the field of History of Science and Technology in India, Dr Rahman has authored, edited and co-edited many books and papers.

C.K. Raju taught mathematics, statistics and did research in mathematical physics for many years. He helped build *Param:* India's parallel supercomputer. He was a fellow at IIAS, Shimla and wrote a book on Time. He is currently engaged in research about time at the interface of science, religion and society at NISTADS, New Delhi.

Vijaya Ramaswamy obtained her PhD from Jawaharlal Nehru University in 1981. In 1985 Oxford University Press brought out her book, *Textiles and Weavers in Medieval South India.* Her second book called *Divinity and Deviance: Women in Virasaivism,* also came out with OUP in 1996. She is an alumni of the School of Oriental and African Studies, London and was senior Fullbright Scholar at the Department of History, University of California, Berkeley. She has published articles on economic history, Indian folklore, religion and women's history in Indian and international journals. She was a Fellow of the Indian Institute of Advanced Study, Shimla from 1992 to 1995. Her recent monograph *Walking Naked: Women Society and Spirituality in South India* has been published by IIAS, Shimla in 1997.

S.A.H. Rizvi is a mathematician specializing in medieval mathematics and astronomy. He received his doctorate in History of Science and has knowledge of many classical languages. He is teaching mathematics in Guru Nanak Dev University, Bidar.

T.M. Srinivasan began his research career on the problems of history of marine sciences in India at the Indian National Science Academy, New Delhi. He has published a number of research papers with (late) Professor N.K. Panikkar and is currently compiling references from primary sources on 'Studies Relating to Agricultural Practices in South India'. At present he is Assistant Director at the Indian Institute of Chemical Technology (formerly Regional Laboratory), Hyderabad.

General Introduction

I

It is understandable that man, shaped by Nature, would like to know Nature. The human ways of knowing Nature are evidently diverse, theoretical and practical, scientific and technological, artistic and spiritual. This diversity has, on scrutiny, been found to be neither exhaustive nor exclusive. The complexity of physical nature, life-world and, particularly, human mind is so enormous that it is futile to follow a single method for comprehending all the aspects of the world in which we are situated.

One need not feel bewildered because of the variety and complexity of the worldly phenomena. After all, both from traditional wisdom and our daily experience, we know that our own nature is not quite alien to the structure of the world. Positively speaking, the elements and forces that are out there in the world are also present in our body-mind complex, enabling us to adjust ourselves to our environment. Not only the natural conditions but also the social conditions of life have instructive similarity between them. This is not to underrate in any way the difference between the human ways of life all over the world. It is partly due to the variation in climatic conditions and partly due to the distinctness of production-related tradition, history and culture.

Three broad approaches are discernible in the works on historiography of civilization, comprising science and technology, art and architecture, social sciences and institutions. Firstly, some writers are primarily interested in discovering the general laws which govern all civilizations spread over different continents. They tend to underplay what they call the noisy local events of the external world and peculiarities of different languages, literatures and histories. Their accent is on the unity of Nature, the unity of science and the unity of mankind. The second group of writers, unlike the generalist or transcendentalist ones, attach primary importance to the distinctiveness of every culture. To these writers human freedom and creativity are extremely important and basic in character. Social institutions and the cultural articulations of human consciousness, they argue, are bound to be expressive of the concerned people's consciousness. By implication they tend to reject concepts like archetypal consciousness, universal mind and providential history. There is a third group of writers who offer a composite picture of civilizations, drawing elements both from local and their common characteristics. Every culture has its local roots and peculiarities. At the same time, it is pointed out that due to demographic migration and immigration over the centuries an element of compositness emerges almost in every culture. When due to natural calamity or political exigencies people move from one part of the world to another, they carry with them, among other things, their language, cultural inheritance and their ways of living.

In the light of the above facts, it is not at all surprising that comparative anthropologists and philologists are intrigued by the striking similarity between different language families and the rites, rituals and myths of different peoples. Speculative philosophers of history, heavily relying on the findings of epigraphy, ethnography, archaeology and theology, try to show in very general terms that particulars and universals of culture are 'essentially' or 'secretly' interrelated. The spiritual aspects of culture like dance and music, beliefs pertaining to life, death and duties, on analysis, are found to be mediated by the material forms of life like weather forecasting, food production, urbanization and invention of script. The transition from the oral culture to the written one was made possible because of the mastery of symbols and rules of measurement. Speech precedes grammar, poetry prosody. All these show how the 'matters' and 'forms' of life are so subtly interwoven.

II

The PHISPC publications on History of Science, Philosophy and Culture in Indian Civilization, in spite of their unitary look, do recognize the difference between the areas of material civilization and those of ideational culture. It is not a work of single author. Nor is it being executed by a group of thinkers and writers who are methodologically uniform or ideologically identical in their commitments. In conceiving the Project we have interacted with, and been influenced by, the writings and views of many Indian and non-Indian thinkers.

The main unity of this Project lies in its aim and inspiration. We have in India many scholarly works written by Indians on different aspects of our civilization and culture. Right from the pre-Christian era to our own time India has drawn the attention of various countries of Asia, Europe and Africa. Some of these writings are objective and informative and many others, based on insufficient information and hearsay, and therefore not quite reliable, but they have their own value. Quality and kind of views keep on changing not only because of the adequacy and inadequacy of evidence but also, and perhaps more so, because of the bias and prejudice, religious and political conviction, of the writers.

Besides, it is to be remembered that history, like Nature, is not an open book to be read alike by all. The past is mainly enclosed and only partially disclosed. History is, therefore, partly objective or 'real' and largely a matter of construction. This is one of the reasons why some historians themselves think that it is a form of literature or art. However, it does not mean that historical construction is 'anarchic' and arbitrary. Certainly there is an important role of imagination in it.

But its character is basically dependent upon the *questions* which the historian raises and wants to understand or answer in terms of the ideas and actions of the past human beings. In a way, history, somewhat like the natural sciences, is engaged in answering questions and in exploring relationships of cause and effect between events and developments across time. While in the natural sciences, the scientist poses questions to nature in the form of hypotheses, expecting to elicit authoritative answers to such questions, the historian studies the past, partly for the sake of understanding it for its own sake and partly also for the light which the past throws upon the present, and the possibilities which it opens up for moulding the future. But the difference between the two approaches must not be lost sight of. The scientist is primarily interested in discovering laws and framing theories in terms of which different events and processes can be connected and anticipated. His interest in the conditions or circumstances attending the concerned events is secondary. Therefore, scientific laws turn out to be basically abstract and easily expressible in terms of mathematical language. In contrast, the historian's main interest centres round the *specific* events, human ideas and actions, not *general* laws. So, the historian, unlike the scientist, is obliged to pay primary attention to the circumstances of the events he wants to study. Consequently, history, like most other humanistic disciplines, is concrete and particularist. This is not to deny the obvious truth that historical events and processes consisting of human ideas and actions show some trend or other and weave some pattern or other. If these trends and patterns were not there at all in history, the study of history as a branch of knowledge would not have been profitable or instructive. But one must recognize that historical trends and patterns, unlike scientific laws and theories, are not general or purported to be universal in their scope.

III

The aim of this Project is to discover the main aspects of Indian culture and present them in an interrelated way. Since our culture has influenced, and has been influenced by, the neighbouring cultures of West Asia, Central Asia, East Asia and South East Asia, attempts have been made here to trace and study these influences in their mutuality. It is well known that during the last three centuries, European presence, both political and cultural, in India has been very widespread. In many volumes of the Project considerable attention has been paid to Europe and through Europe to other parts of the world. For the purpose of comprehensive cultural study of India the existing political boundaries of South Asia of today are more of a hindrance than help. Cultures, like languages, often transcend the bounds of changing political territories.

If the inconstant political geography is not a reliable help to the understanding of the layered structure and spread of culture, a somewhat comparable problem is encountered in the area of historical periodization. Periodization or segmenting time is a very tricky affair. When exactly one period ends and another begins is not precisely ascertainable. The periods of history designated as ancient, modern and mediaeval are purely conventional and merely heuristic in character. The varying scopes of history, local, national and continental or universal, somewhat like the periods of history, are unavoidably fuzzy and shifting. Amidst all these difficulties, the volume-wise details have been planned and worked out by the editors in consultation with the Project Director and the General Editor. I believe that the Editors of different volumes have also profited from the reactions and suggestions of contributors to individual chapters in planning the volumes.

Another aspect of Indian history which the volume editors and contributors of the Project have carefully dealt with is the distinction and relation between civilization and culture. The material conditions which substantially shaped Indian civilization have been discussed in detail. From agriculture and industry to metallurgy and technology, from physics and chemical practices to the life sciences and different systems of medicines—all the branches of knowledge and skill which directly affect human life—form the heart of this Project. Since the periods covered by the PHISPC are extensive—pre-history, proto-history, early history, mediaeval history and modern history of India—we do not claim to have gone into all the relevant material conditions of human life. We had to be selective. Therefore, one should not be surprised if one finds that only some material aspects of Indian civilization have received our pointed attention, while the rest have been dealt with in principle or only alluded to.

One of the main aims of the Project has been to spell out the first principles of philosophy of different schools, both pro-Vedic and anti-Vedic. The basic ideas of Buddhism, Jainism and Islam have been given their due importance. The special position accorded to philosophy is to be understood partly in terms of its proclaimed unifying character and partly it is to be explained in terms of the fact that different philosophical systems represent alternative world-views, cultural perspectives, their conflict and mutual assimilation.

Most of the volume editors and at their instances the concerned contributors have followed a middle path between extremes of narrativism and theoreticism. The underlying idea has been this. If in the process of working out a comprehensive Project like this every contributor tries to narrate all those interesting things that he has in the back of his mind the enterprise is likely to prove unmanageable. If, on the other hand, particular details are consciously forced into a fixed mould or pre-supposed theoretical structure, the details lose

(i) *Trayī,* the triple Veda; (ii) *Ānvīkṣikī,* logic and metaphysics; (iii) *Daṇḍa-nīti,* science of Government; (iv) *Vārtta,* practical arts such as agriculture, commerce, medicine, etc. Manu speaks of a fifth *Vidyā,* viz., *Ātma-vidyā,* knowledge of self or of spiritual truth. According to many others, *Vidyā* has fourteen divisions, viz., the four *Vedas,* the six *Vedāṅgas,* the *Purāṇas,* the *Mīmāṁsā, Nyāya,* and *Dharma* or law. At times the four *Upa-vedas* are also recognized by some as *Vidyā. Kalās* are said to be 33 and even 64.

In the classical tradition of India, the word *Śāstra* has at times been used as synonym of *Vidyā. Vidyā* denotes instrument of teaching, manual or compendium of rules, religious or scientific treatise. The word *Śāstra* is usually found after the word referring to the subject of the book, e.g., *Dharma-śāstra, Artha-śāstra, Alaṁkāra-śāstra* and *Mokṣa-śāstra.* Two other words which have been frequently used to denote different branches of knowledge are *Jñāna* and *Vijñāna.* While *Jñāna* means knowing, knowledge, especially the higher form of it, *Vijñāna* stands for the act of distinguishing or discerning, understanding, comprehending and recognizing. It means worldly or profane knowledge as distinguished from *Jñāna,* knowledge of the divine.

It must be said here that the division of knowledge is partly conventional and partly administrative or practical. It keeps on changing from culture to culture, from age to age. It is difficult to claim that the distinction between *Jñāna* and *Vijñāna* or that between science and art is universal. It is true that even before the advent of modem age, both in the East and the West, two basic aspects of sciences started gaining recognition. One is the *specialized character* of what we call scientific knowledge. The other is the concept of *trained skill* which was brought close to scientific knowledge. In the medieval Europe, the expression 'the seven liberal sciences' has so often used simultaneously with 'the seven liberal arts', meaning thereby the group of studies by the *Trivium* (Grammar, Logic and Rhetoric) and *Quadrivium* (Arithmetic, Music, Geometry and Astronomy).

It may be observed here, as has already been alluded to earlier, that the division between different branches of knowledge, between theory and practice, was not pushed to an extreme extent in the early ages. *Praxis,* for example, was recognized as the prime *techne.* The Greek word *technologia* stood for systematic treatment, for example, of Grammar. *Praxis* is not the mere application of *theoria,* unified vision or integral outlook, but it also stands for the active impetus and base of knowledge. In India one often uses the terms *Prayukti-vidyā* and *Prayodyogika-vidyā* to emphasize the practical or applicative character of knowledge. *Prayoga* or application is both test and base of knowledge. Doing is the best way of knowing and learning.

That one and the same word may mean different 'things' or concepts in different cultures and thus create confusion has already been stated before. Two such words which in the context of this Project under discussion deserve special mention are *dharma* and *itihāsa.* Ordinarily *dharma* in Sanskrit-rooted languages is taken to be conceptual equivalent of the English word *religion.* But, while the meaning of religion is primarily theological, that of *dharma* seems to be manifold. Literally *dharma* stands for that which is established or that which holds people steadfastly together. Its other meanings are law, rule, usage, practice, custom, ordinance and statute. Spiritual or moral merit, virtue, righteousness and good works are also denoted by it. Further, *dharma* stands for natural qualities like burning (of fire), liquidity (of water) and fragility (of glass). Thus one finds that meanings of *dharma* are of many types—legal, social, moral, religious or spiritual, and even ontological or physical. All these meanings of *dharma* have received due attention of the writers in the relevant contexts of different volumes.

This Project, being primarily historical as it is, has naturally paid serious attention to the different concepts of history—epic-mythic, artistic-narrative, scientific-causal, theoretical and ideological. Perhaps the point that must be mentioned first about history is that it is not a correct translation of the Sanskrit word *itihāsa*. Etymologically, it means what really happened (*iti-ha-āsa*). But, as we know, in the Indian tradition *purāṇa* (legend, myth, tale, etc.), *gāthā* (ballad), *itivṛtta* (description of past occurrence, event, etc.), *ākhyāyikā* (short narrative) and *vaṃśa-carita* (genealogy) have been consciously accorded very important place. Things started changing with the passage of time and particularly after the effective presence of Islamic culture in India. Islamic historians, because of their own cultural moorings and the influence of the Semitic and Graeco-Roman cultures on them, were more particular about their facts, figures and dates than their Indian predecessors. Their aim to bring history close to statecraft, social conditions and the lives and teachings of the religious leaders imparted a mundane character to this branch of learning. The Europeans whose political appearance on the Indian scene became quite perceptible only towards the end of the eighteenth century brought in with them their own view of historiography in their cultural baggage. The impact of Newtonian Revolution in the field of history was very faithfully worked out, among others, by David Hume (1711-76) in *History of Great Britain from the Invasion of Julius Caesar to the Revolution of 1688* (6 vols., 1754-62) and Edward Gibbon (1737-94) in *The History of the Decline and Fall of the Roman Empire* (6 vols., 1776-88). Their emphasis on the principles of causality, datability and continuity/linearity of historical events introduced the spirit of scientific revolution in European historiography. Introduction of English education in India and the exposure of the elites of the country to it largely account for the decline of the traditional concept of *itihāsa* and the rise of the post-Newtonian scientific historiography. Gradually Indian writers of our own history and cultural heritage started using more and more European concepts and categories. This is not to suggest that the impact of the European historiography on Indian historians was entirely negative. On the contrary, it imparted an analytical and critical temper which motivated many Indian historians of the nineteenth century to try to discover and represent our heritage in a new way.

VI

The principles which have been followed for organizing the subjects of different volumes under this Project may be stated in this way. We have kept in view the main structures which are discernible in the decomposible composition of the world. The first structure may be described as physical and chemical. The second structure consists, broadly speaking, of biology, psychology and epistemology. The highest and the most abstract structure nests many substructures within it, for example, logic, mathematics and musical notes. It is well known that the substructures within each structure are interactive, i.e., not isolable. The more important point to be noted in this connection is this. The basic three structures of the world, viz., (a) physico-chemical, (b) bio-psychological, and (c) logico-mathematical are all simultaneously open to upward and downward causation. In other words, while the physico-chemical structure can causally influence the bio-psychological one and the latter can causally influence the most abstract logico-mathematical, the reverse process of causation is also operative in the world. In spite of its relative abstractness and durability, the logico-mathematical world has its downward causal impact on our bio-psychological and epistemological processes and products. And the latter can also bring about change in the structures of physical world and its chemical composition. Applied physics and bio-technology make the last point abundantly clear.

Many philosophers, life-scientists, and social scientists highlight the point that nature loves hierarchies. Herbert Simon, the economist and the management scientist, speaks of four steps of partial ordering of our world, namely, (i) chemical substances, (ii) living organisms, tissues and organs, (iii) genes, chromosomes and DNA, and (iv) human beings.

the social organizations, programmes and information process. All these views are in accord with the anti-reductionist character of our Project. Many biologists defend this approach by pointing out that certain characteristics of biological phenomena and process like unpredictability, randomness, uniqueness, magnitude of stochastic perturbations, complexity and emergence cannot be reduced without residue to physical laws.

The main subjects dealt with in different volumes of the Project are connected not only conceptually and synchronically but also historically or diachronically. For pressing practical reason, however, we did not aim at presenting prehistorical, protohistorical and historical past of India in a continuous or chronological manner. Besides, it has been shown in the presentations of the PHISPC that the process of history is non-linear. And this process is to be understood in terms of human praxis and absence of general laws in history. Another point which deserves special mention is that the editorial advisors have taken a conscious decision not to make this historical Project primarily political. We felt that this area of history has always been receiving extensive attention. Therefore, customary discussion of dynastic rule and succession will not be found in a prominent way in this series. Instead, as said before, most of the available space has been given to social, scientific, philosophical and other cultural aspects of Indian civilization.

Having said this it must be admitted that our departure from conventional style of writing Indian history is not total. We have followed an inarticulate framework of time in organizing and presenting the results of our studies. The first volume, together with its Parts, deals with the prehistorical period to AD 300. The next two volumes, together with their parts, deal with, among other things, development of social and political institutions and philosophical and scientific ideas from AD 300 to the beginning of the eleventh century AD. The next period with which this Project is concerned spans from the twelfth century to the early part of the eighteenth century. The last three centuries constitute the fourth period covered by this Project. But, as said before, the definition of all these periods by their very nature are inexact and merely indicative.

Two other points must be mentioned before I conclude this General Introduction to the series. The history of some of the subjects like religion, language and literature, philosophy, science and technology cannot for obvious reason be squeezed within the cramped space of the periodic moulds. Attempts to do so result in thematic distortion. Therefore, the reader will often see the overflow of some ideas from one period to another. I have already drawn attention to this tricky and fuzzy and also the misleading aspects of the periodization of history, if pressed beyond a point.

Secondly, strictly speaking, history knows no end. Every age rewrites its history. Every generation, beset with new issues, problems and questions, looks back to its history and reinterprets and renews its past. This shows why history is not only contemporaneous but also futural. Human life actually knows no separative wall between its past, present and future. Its cognitive enterprises, moral endeavours and practical activities are informed of the past, oriented by the present and addressed to the future. This process persists, consciously or unconsciously, wittingly or unwittingly. In the narrative of this Project we have tried to represent this complex and fascinating story of Indian civilization.

Centre for Studies in Civilizations
Delhi, April, 1998

D.P. CHATTOPADHYAYA
General Editor and Project Director

Introduction

Volume III, Part one of the Project of the History of Indian Science, Philosophy and Culture covers some aspects of the development of science and technology and their interface with society from the tenth to the eighteenth century. It provides a general perspective of science and technology in two separate chapters, besides covering a few other areas like astronomy, mathematics, ideas of time and space, and development of chemistry and food science. In the area of technology it covers developments relating to minerals and metals, agriculture and irrigation, the latter particularly in south India. It also has a chapter on the role of paper technology and the spread of paper production centres in India. There is a chapter on the role of women saints in the Bhakti movement and another chapter on the nature of Bhakti and Sufi movements and their connection with science. The last chapter was necessitated by a remark of Professor Abdus Salam, Nobel Laureate, that the rise of Sufi movement led to the decline of science in Islamic culture. It brings out the fact that, though there were contributions to science, the social and other concerns then obtaining in India gave rise to certain popular movements, which had essentially religious character.

There are many other important areas which could not be covered in this volume either because the concerned specialists who were approached did not respond at all or failed to fulfil their commitments. These areas include architecture, geology, geography, biology, textiles and ceramics. Medicine is not included as it is being covered in another volume. These areas represent major developments during this period and ought to be covered.

There are few lacunae. This relates to some contributions covering early period extensively and giving limited reference to the latter period or omitting the coverage in one chapter. This is due primarily to the framework of expertise of the author. It was felt that it should be left as such, as some features were covered in other chapters.

Another very important area that could not be covered due to paucity of information and time was the role of women in society during this period. We have many examples of women from the nobility who were highly accomplished and talented in poetry, literature and other arts. Noorjehan, for instance, was not only a great administrator but was also responsible for the development of various dresses and related artifacts. Noorjehan's mother who made rose water for the palace also discovered the essence of rose which she called *Itr Jehangiri*. Other women were well-versed in cloth-making, dyeing, printing, food preservation, preparation of medicines, etc. Their contributions need to be highlighted.

This period is very interesting and significant from several points of view. There is a vast literature available which requires to be searched. The availability of a large number of manuscripts, more than ten thousand, shows the spirit of intellectual activity in the field of science, besides other areas of scholarship. There is a need also to look into the available literature in Arabic and Persian and to collate these with the Sanskritic texts to understand the nature of borrowings, the translations which were carried out, and the extent of interaction which was part of the culture of that period. Apart from the original texts, there are a large number of commentaries on major books and their shortened and summarized versions, which were probably used as text books by the students. It would also be useful to know the variations in the texts that occurred during that period.

A proper understanding of the interaction of Arabic and Persian scholars with Sanskrit scholars, which appears to have been encouraged by various kings and nobles, is important. A cursory look at different cultures would reveal that whenever such interactions took place, there occurred a spurt in scientific activity. The developments in Greece were the result of absorption by the Greek scholars of Egyptian, Phoenician, Persian and Indian scientific knowledge. The Islamic scientific revolution was primarily due to the availability of Indian and Greek scientific literature. The European scientific revolution owes much to the availability of Islamic and Indian scientific literature. The question that now begs an answer is why this large scale interaction, which took place in India during this period, did not lead to new developments in the sciences? Why was it limited to mostly translation activity, essentially to assimilate different linguistic traditions? Was it due to the nature of the society and the demand it made on the sciences? Was it due to the levels of Arabo-Persian and Sanskrit literature being the same? Or was it due to religious prejudices which prevailed in the society, as each linguistic tradition wanted to maintain its own purity? These and many other questions require further research.

There has been a tendency to study developments in India in the context of its own traditions. However, what is required to be done is to correlate Indian developments with developments during the same period in other countries, particularly the neighbouring countries of central and western Asia and China. Such a study will provide a comparative view and an insight into the nature of Indian developments. It does appear from a cursory glance at literature that India, China, central Asia and west Asia were in a continuous dialogue and exchange of knowledge and technological know-how, interacting and giving and taking from one another. Another dimension of the developments during this period was the growth of both secular and religious literature. Many kings like Sikandar Lodhi and Akbar, in particular, promoted secular knowledge. Three texts provide a significant insight into the intellectual development of the period: Al-Beruni's *India,* Abul Fazl's *Ain-e-Akbari* and *Majmua-Al-Bahrain* of prince Dara Shikoh. While Al-Beruni gives an outsider's view of the development of science in India, *Ain-e-Akbari* gives a detailed account of the social and intellectual development of the country and provides an insight into the attitude and outlook of the educated elite, particularly the scientific and secular outlook. Prince Dara Shikoh's book *Majmua-Al-Bahrain* (which means 'mingling of two oceans') provides a comparative understanding of the scientific terminology and concepts in Hindu and Islamic intellectual traditions and also of the religious terminology and concepts of the two systems. It also shows his efforts at unifying the secular and the spiritual traditions of the country. Such literature reveals the efforts at bringing under one system the multi-cultural traditions as well as the philosophic, religious and scientific ideas prevalent during this period. This particular feature of the literature of this period assumes some significance in the context of the re-thinking which is now underway in the area of science in the contemporary period.

This raises the question about the nature of science in medieval and contemporary India. Modern science has a well-defined methodology and refined techniques to acquire new knowledge and institutionalized systems for its accumulation and development. It also has a well-defined purpose as a part of the framework of contemporary society. It is non-religious and objective and its conclusions are timeless and its truths verifiable—features that are equally valid everywhere irrespective of culture or country.

What we now call the natural sciences were actually a part of the concern of the scholars; consequently, we notice that the scholars contributed to literature, poetry, philosophy and religion as well as to the sciences. Indeed, we have examples of some of the Sufis practicing alchemy before they became Sufis. They were educated in secular as well as religious thought. For instance, Abul Fazl patronized Mulla-Abdul-Qadir-Badauni, a religious divine who was well-versed in science and who was highly critical of the secular philosophy and policies followed by Akbar.

As already mentioned, there were linkages between man and the environment as well as the cosmic phenomena. There was also an emphasis on continuities, as was evident from the poems of Rumi, wherein he talks about the transformation of minerals to plants, of plants to animals, of animals to man, and of man to cosmic phenomena.

As regards the validity of knowledge, the sacred texts were always the standard measure, even though the explanation of scientific knowledge was in terms of its own rationality and logic.

Another dimension of science was its relationship to the needs of society. Astronomical developments were closely related to the needs of agriculture and astrology for social and individual purposes. Mathematical developments had their uses in tax collection, management of revenue, division of property and other such needs. Metallurgy was developed to make various artefacts used in everyday life as well as for production of armaments for the army. However, the development of science and technology was rather limited because the evolution of society from its agricultural base to an industrial base did not take place. Another possible reason could be the non-institutionalization of science, since scholars needed patronage and they moved from place to place in search of greener pastures. As a result, therefore, there was lack of continuity in scientific effort.

The period was also of considerable uncertainty in regard to social life. There was rise and fall of kingdoms and, within a dynasty, rise and fall of kings. This instability and uncertainty were not conducive to planning for the future, and the people lived for the present as best as they could, as long as they could. As a result, the resources that were generated were spent on non-resource generating activities—building of palaces and places of worship and celebrations and festivities to mark different occasions of one's life. In other words resources were not available for the purpose of development; instead these were used to meet the needs of the aristocracy and their lavish style of living. Craftsmen and artisans, except those who were highly honoured, lived life from one day to another; they were not able to generate resources to improve the tools and equipment they used for producing their goods. This is evident from the lack of development of machinery during this period. This, however, led to another dimension, which has been a special feature of Indian culture, wherein the artisans and craftsmen concentrated on the development of skills with simple tools and equipment, to produce the most sophisticated and refined products, which were highly prized throughout the world. Though the concepts of innovation and discovery were not actively pursued, those happened only by chance and, consequently, the developments were slow and incremental over a long period of time. This might have also been due to the fact that production was adequate to meet the needs and standards of living during the period. There are a few exceptions to this. For instance, the innovative effort of Fathullah Shirazi at the court of Akbar led to the development of a series of mechanical devices, but it looks as if these were only models and did not become a part of the production system.

The major concerns of the period were, of course, the nature of human life, individual salvation and problems connected with life after death. Consequently, the people concentrated on salvation through religious effort which led to the development of such movements as Bhakti and Sufism. These movements were also the outcome of social problems arising out of philosophical and theoretical religion, which most people found difficult to understand and follow; and this led them to evolve a more popular religious approach, which not only allowed for individual satisfaction but also met the emotional needs of the people. In contrast to theoretical and philosophical science, there was also popular science, a mixture of scientific ideas and fact with popular beliefs, myths and folklore. This led Al-Beruni to remark that Indian science was like pearls mixed with cow-dung. This was different from philosophical and theoretical science which was the preserve of the elites. Scientific knowledge and technical practices were part of the culture of the period and were used by the people in their everyday life. However, there was a sharp division between science and technology; while science was the preserve of the elite, technology was limited to artisans and craftsmen. Indeed, the elite considered it below their dignity to work with their hands. This lack of interaction between science and technology led to the absence of technology, posing obstacles to scientific enquiry and to science offering solutions for technological problems.

While the scientific tradition was oral as well as written after the emergence of paper technology, the technological tradition remained largely oral and observational; the people imbibed the latter largely through apprenticeship. We have very few books on technology from that period. There was also large scale migration of scholars from central and western Asia, as a result of invasion by Changez Khan and also the genocide of people in major centres of learning in central and western Asia. Those who came from these areas were already aware of Indian science, philosophy and religious traditions. This is evident from the fact that Al-Beruni, who came to India in the eleventh century, already had books on Indian science, philosophy and religion in his library. There is also evidence that those who came to India were eager to learn more and more about the Indian philosophy, science and religion, and there was large scale translation of Indian texts into Persian. The latter also indicates that the educated elites were perhaps bilingual. The translation activity on a large scale became possible due to the availability of paper after the introduction of the paper technology in India. This interaction was a part of a continuous process which has been the characteristic feature of the Asian culture.

Two of the characteristic features of the period were; firstly, as a result of the sultanate and later mughal empire, the interesting interaction with central Asia, Iran and west Asia. This was reflected in the flow of scholars to India, but more in influencing the cultural ethos. The latter was reflected in the living style, adoption of dresses, both male and female as well as in food. Central Asian and Iranian, cuisine came to be a part of the dietary habits, in particular varieties of Biryani, Pulao, Kebabs of different types and a number of meat dishes with various spices as ingredients and in the method of cooking. Secondly, the entire development in arts and crafts was patronized by the kings and nobility, and the products were made to suit their tastes and desires. Certain types of textiles, carpets, ceramic materials, brass, leather and other such products were of their exclusive use. In order to suit their taste and luxurious living, they imported designs and materials and artisans and craftsmen from central Asia and Iran. Later attempt was made to blend it with Indian designs and products made by Indian craftsmen.

Another feature of the culture of the Kings and nobility was the effort of each to have a product or build a structure by which their name and fame should spread and for which they should be known in posterity. Looking at these scientific developments in medieval India and contemporary development of science, we may infer that science is both a human endeavour and a social construct; while endeavour is a continuous process, the construct differs from period to period.

A. RAHMAN
Editor

Section One

SCIENCE

CHAPTER I

A Perspective of Indian Science

A. Rahman

I. INTRODUCTION

Science has dual aspects: Firstly, as a method of acquiring knowledge, its systematization, interpretation and drawing of conclusions from it help widen the horizons of man's understanding of the environment and enable him to use it to shape his future. Secondly, arising out of the use of this knowledge, it helps shape man's social, economic and cultural life, and it thus becomes a part of the political process.

To understand the historical development of science one has to understand both these aspects—the evolution of the method of science as well as the political role it plays in society. In contemporary society, one has to include the economic role as well.

To understand the political role one has to carefully study the language through which science is communicated: what it communicates and what it withholds, as well as to whom it is communicated and from whom it is withheld. One has also to study the base and spread of science in society in a particular culture in a defined period of history, the area it covers and the areas it is not able to cover or leaves out. The latter may be either due to inadequacy of methods or means available or due to social and political constraints, when it is not found advisable to tread the thorny path.

A critical study of history of science in its social and cultural context would reveal a constant effort to control science, to meet the purposes and goals of the State. This is done both by containing the spread of science and by imposing on it myths and dogmas. Every religious group maintains that everything worth knowing is available in the sacred text, and all one has to do is to unfold the meaning of what is given by interpreting it properly. Indeed, it is even suggested that if there is any contradiction between scientific knowledge and the sacred text, efforts should be made to modify the former in conformity with the latter. New ideas as they were generated in different societies came up against the dead weight of tradition, and very often scientists espousing new ideas and promoting new knowledge were punished—some even had to pay with their lives.

Looking at the knowledge base of a society, it does appear to be a part of the State policy to limit it to the ruling elite, while promoting myths for the masses. In this process the priestly class, and where this class did not exist, the theologians or politicians were utilized by the State. This was so in ancient Egypt, Greece, India, the Islamic world and Europe. We find this in evidence once again in contemporary society.

Isocrates, explaining the purpose of an Egyptian religious priest, says:

> The pious practices which he introduced were many and various; for he established by law that they should offer reverence and honour animals which are despised among us, not because he was under any misapprehension as to the power of these creatures, but for two other reasons. The first was that he thought it proper to accustom the mob to obey any commands that were given to them by their supervisors; the second, that he wished to test by their attention to these public observances, the sentiments his subjects might entertain on matters which were difficult to observe. For he thought that men who despised these little observances might very well also feel contempt for more important things, while he could rely on those who displayed their piety to be equally law abiding in every other particular.[1]

In Greece, Critias, a relative of Plato, gives his ideas of the political origin of religion as follows:

> When the law hindered indeed wrongful works done by open violence, but men continued to do them by stealth, some shrewd and wise thoughted men found an object of awe for mortals, that these might be some object of dread to the wicked even if they do or say or think anything in secret. Whence he brought in the divinity... telling them that there is Deity... vigorous with imperishable life, hearing and seeing with the mind, with sense thought attending to these things, and clothed with a divine nature, who will hear all that is said among mortals and will have power to see all that is done.[2]

Aristotle expresses similar views when he says:

> myths that have been introduced to persuade the multitude and on account of their utility in regard of Social custom and Public good.[3]

Throughout history, when scientific knowledge created a new awareness of the environment and opened up a possibility of enlightenment for the people, efforts were made to contain knowledge and promote myths for popular consumption. With the advent of industrial society one notices propagation of a series of political myths as well as the exploitation of religion for political purposes.

In the study of history of science both the dimensions, as stated earlier—namely, the method of science and its role in society—have to be carefully studied. This is important because in each period of the development of science one may notice the prevalence of 'counter knowledge' (i.e. knowledge that negates the main conclusions of science).

It may be worthwhile to briefly describe here the method of science as it has evolved to indicate the nature of conflict. The first dimension of the method of science comprises observation and experimentation to collect the basic data; the data thus collected are then analysed and systematized to draw preliminary conclusions, and correlated with the framework of existing theories or otherwise used to develop alternative hypotheses; after their validation according to available procedure, theories are formulated. The second dimension covers the manner of doing science, including the use of instruments, the teams which operate, etc. The third dimension covers the context of science, its social and cultural implications, political linkages, philosophical meanings, and the interpretations given to the various dimensions. Finally, the fourth dimension is the language in which science is written and communicated, both amongst the scientific community and the people. To describe the scientific method in these words is neither to deny the various stages of its development in different periods of history in different societies nor to belittle the constraints of its political framework.

Each of these steps and dimensions of science are often subject to critical comments and doubts of those who think that there are alternative ways of acquiring knowledge, that the scientific method leaves out many dimensions of knowledge, that its contents are narrow and comprise only those areas of knowledge which can be covered by its methodology or the instruments used. Reality is large and many-dimensional and the scientific methods and means of gaining knowledge could be compared to a fishing-net: the size of the hole in the net restricts the size of the catch and, however small the mesh, something would always escape the net. Very often, intuitive knowledge, poetic and artistic perceptions and sensibilities are mentioned to point out the limitations of scientific approach leading to limitation of knowledge. In addition, the mystic experience is cited as feasible means of acquiring knowledge.

Though the poetic or artistic and the mystic experience and perceptions cannot be denied, they are highly individualistic and cannot be replicated to form the basis of common knowledge, nor can they be validated by any means. Further, it is also not possible to analyse the experiences to know their nature and the perceptions they generate or the sensibilities they awaken. In societies, in every culture and in every period, the two streams have co-existed often independently, but occasionally interacting and borrowing from one another, to provide a new perception or a new dimension to reality. However, occasionally the alternative perspective of acquiring knowledge becomes an anti-science movement, and then a crisis begins to shape. This happens when the State (i.e. the political rulers and the dominant elite) begins to fear the new knowledge and its applications and launches an attempt on the method and content of science to preserve the status quo. In such a situation the alternatives, as Farrington so succinctly puts, are:

> Either we must base our civilization more thoroughly on scientific foundations, or we must destroy science itself. Both processes are taking place in the world today.[4]

In this effort, either religion or an ideology is used to mobilize people who do not share the scientific rationality, since no effort has been made to disseminate the knowledge and its rationality to them or they have been kept out of the gains of development. A cursory look at the history of different cultures would bear this out.

In the preparation of this volume, whereas each contributor would concentrate on the subject concerned, he may or may not touch upon its social, cultural or political dimensions, or philosophical implications. It would be worthwhile therefore to indicate in the first chapter some features of historical writing as it has evolved in the West and to point out the linkages and interconnections of scientific activity with other aspects of human endeavour.

II. CONCEPTUAL FRAMEWORK OF HISTORY OF SCIENCE IN INDIA: ISSUES AND PROBLEMS

European Approach to History of Science

European science, it may be stressed, was part of a movement for revolt against medieval system of production, controlled by feudal nobility, and the church which controlled the intellectual climate in Europe. It was a revolt to seek and develop alternatives to the production system as well as to search for a new intellectual framework.

Agricola's (1490-1539) *De Re Metallica*[5] not only gives details about mining and metals with illustrations, but also provides economic reasons for undertaking mining as against agriculture and dispels various superstitions then prevalent about mining. In other words, it provides both economic reasons as well as the new outlook based, not on ancient texts, but on observations and experimentation. The same approach is found in books of botany and zoology and in the comments and notes of European travellers to other continents.

The techno-economic developments also engendered new social and technological organization: instead of craft guilds, the foundation was laid for a factory system incorporating wage labour, the concepts of input, output and productivity, and the new management system. It also created conditions for such mechanical instruments as the clock. Warfare created a demand for regular supply of weapons and also led to the manufacture of cannons, guns and gunpowder.

The change in intellectual framework began with the challenge to authority and criticism of established doctrines. In the arts it began with realism and a vision and perspective of nature, including the study of man, his anatomy and physiology. In medicine, it questioned the authority of Galen, starting from Vesalius to Harvey.

Leonardo da Vinci (1452-1519) provided alternatives in art, architecture, engineering, technology as well as in warfare. His endeavours show a range of changes both in science and technology, its methodology as well as rigorousness. In other words, in the whole range of intellectual pursuit—astronomy, mathematics, medicine, engineering, architecture, art and literature—we find a new framework and new horizons opening up.

What is now called a scientific outlook, apart from helping the development of methodology for collecting and analysing facts and developing hypotheses, theories and laws of nature, came to be applied to social systems, by collecting social data (e.g. by Quetelet) and analysing and drawing conclusions from them. In doing so, a parallel was drawn between man and nature and the use of natural laws to apply them to human behaviour and social organization. Mechanical philosophy, as it was developed in the natural sciences, was later applied to the functioning of society, by people like Locke and others.[6]

These developments, since they differed from the productive systems and ethos, were effectively used by the west to develop a framework of writing history of science designed to marginalize the Asian contribution to science and technology, while borrowing from Asian developments as a base for its own growth. At the same time, Europeanized Greece was built up as a source for the development of European science and philosophy.[7] And the developments in different branches of science, as a beginning of new science, thus came to be attributed to Greece. In writing the history of science and technology it was made out that the story began with Greece. The period after the eclipse of Greece and the beginning of these new developments after the Renaissance in Europe, was called the Dark Ages. All developments and the role of science in Asia from the tenth century to the sixteenth and seventeenth centuries were reduced to a passive phase of translating Greek science into Asian languages, thus preserving it and later passing on the treasure to Europe, where it flourished again. This European framework of history of science should be discarded and the historical development of science be studied afresh in the context of cultural and social developments on the one hand and the purpose it served in society on the other.

The second dimension and framework for writing history of science as it evolved in the nineteenth century in Europe arose as a result of the development of industry. As a result of each industry developing a particular branch of science, chronological and stepwise development of each branch of science came to be recorded This recording developed the notion of causal and linear development, each step laying the foundation for the next chain of developments. Such a picture also delinked the interconnections and linkages scientific developments had with economic growth, political policies, cultural ethos and the underlying philosophy which provided the underpinning for the then contemporary developments in various fields. Moreover, it also further marginalized Asian scientific development as it had a different framework.

Growth of Science and Linkages with Cultural Areas

India, though taken as one political unit today, has varied geographical regions and ecosystems. In different historical periods, growth of humans differed, as a result of which levels of agricultural development, technical and scientific development also differed.[8]

In the historical period there were also radical changes. For instance, during the Sultanate period in the north of India, there was a break with the south, leading to some changes and innovations in cultural history, particularly through the introduction of new technologies. The same applies to west and south India consequent to the establishment of the Begara dynasty in Gujarat and Bahmani kingdoms in the south and deep south.

The concept of a nation state which developed along with the growth of industrialization disrupted the concept of *cultural areas*, which could be applied to pre-industrial societies. Actually, the development of the concept of nation state divided the growth of science and also technologies to the boundaries of the State which laid claim to the achievements of science as a part of other chauvinistic claims. If one looks carefully at the major periods of development of science, one may notice its growth as part of the development of a *culture area*, flowing in from the neighbouring areas. Greece, regarded as a fountain-head of European science, was part of Phoenician and Egyptian culture.[9] The development of science in Greece was, indeed, an offshoot of the earlier developments in Egypt, Phoenicia, Mesopotamia and possibly Iran and India. Greek philosopher-scientists travelled to parts of north Africa and west Asia and drew abundantly from the scientific developments and the reservoirs of knowledge in these areas. References to Iranian science are found in the plays of Aristophenes and Euripides. Commonality of concepts and similarity of some developments point to interaction with India as well. Greek science was distinctive in developing logic and working out theories about nature and natural phenomena.

The development of science in the *Arabian Culture Area*, starting from Baghdad, drew from the indigenous knowledge, particularly from India, on the basis of extensive translations from Sanskrit and Pali, and also from Greece through extensive translations carried out of Greek texts. Like the earlier Greek developments, it became a churning pot of the three scientific traditions, namely, west Asian and north African, Indian and Greek. With the spread of the *Arabic Culture Area*, from Spain and north Africa to China, with Islam as a vehicle, the Arabic science absorbed the knowledge and technologies of these countries. Similarly, when one examines the European developments, one notices the impact, not only of Greek science, but also of Arabic and Indian science; though it is only recently that it is being researched and being accepted. The interaction of Indian science with west Asian and central Asian culture continued over long periods. In fact, it would not be wrong to say that it represented one tradition. Another feature of these developments was that, along with the growth of science in a culture area, one language became dominant and was accepted as the language of science. Greek, Sanskrit, Arabic and Latin, and later French, German and now English became the dominant languages of science during different periods of history.

The study of Indian science in the context of culture area raises many questions:

> Was it totally indigenous or did it also receive and absorb knowledge from other culture areas, i.e. from outside the borders of present India? If the latter is true, what were the inputs it received?

These and related questions assume considerable significance in view of the fact that scientific and related texts do not throw any light on these aspects, nor do they mention any sources outside India. The literature from Greece, Rome, west Africa, the Arab countries, Iran, central Asia and China do mention the development of sciences in India, but there is little mention in Indian texts of the developments outside.

> Does this mean that the Indian scientists (i.e. the Brahmans who were really the scientists and custodians of knowledge) had insulated themselves from any outside influences other than the literature which they produced? If that was so, then what was the role of other groups?

We know, for instance, that Buddhists travelled a lot and carried along the scientific and other knowledge developed in India throughout the world. Wherever they went—Iran, Afghanistan, central Asia or China[10]—they disseminated Indian science. Arnold Pacey mentions the role of Buddhist monks, not only in the dissemination of knowledge but also in the promotion of technology. According to him an Indian in AD 644, was able to identify soils containing saltpetre (which could be identified by its purple flame when introduced to fire). He further states that Indian knowledge had influenced the development of chemistry in China and the formulation of a recipe for production of gun powder.[11]

> If that was so then the question arises: Was it a one-sided traffic? Or did they bring back to India knowledge from the countries they visited? And if the latter was true, how was this knowledge absorbed into Indian science?

The insulation of Indian scientists, their lack of knowledge of the growth and development of science in other countries, is evident from the remarks of Fa Hian when he came to Patliputra. According to him, as stated by Needham, the scholars of Patliputra were vain and considered no other country had any science. Al-Beruni had something very similar to say centuries later:

> According to their own belief, there is no other country on earth but theirs, no other race of man but theirs and no created beings besides them have any knowledge or science whatsoever. Their haughtiness is such that if you tell them of any science or scholar in Khurasan and Persia, they will think you to be both an ignoramus and a liar.[12]

Harsh words indeed, but he adds in the same passage:

> If they travelled and mixed with other Nations they would soon change their mind, for their ancestors were not as narrow minded as the present generation is. One of their Scholars, Varahamira, in a passage where he calls on the people to honour the Brahmans says: 'The Greeks though impure, must be honoured, since they are trained in Sciences and therein excelled others. What then are we to say of Brahman, if he combines with his purity the height of science.' In the former times, the Hindus used to acknowledge that the progress of science due to Greeks is much more important than that which is due to themselves.[13]

Al-Beruni's quotation from Varahmira is important from two points of view. Firstly, it brings out very clearly the recognition by ancient Indian scientists of Greek science and scientists. Secondly, one has to analyse how far this knowledge influenced Indian scientific developments. In astronomy, the translation of two texts does give us an idea, but then what about mathematics, medicine and other areas?

It is quite possible that Indians, when they travelled to other countries, were aware of the development of knowledge, acknowledged its value and used it in their contributions; but when conservatism set in and foreign travel was tabooed by the Brahmans, the isolation of Indian scientists began and they developed the traits pointed out by the Chinese scholar and Al-Beruni. The consequences of this social restriction on the intellectual climate in India and the growth (or stagnation) of Indian science ought to be studied.

If there were contacts with Greece and later with Rome, what about the contacts with west Asia and central Asia and the influence of scientific knowledge of these areas on Indian science? The contact with west and central Asia has been there since antiquity. According to

Kosambi,[14] there were similarities between Iranian, Sumerian and Indian religious and other texts, and there were many common myths. Further, the language that developed became a means of intercourse over vast regions.[15] Again, according to Kosambi, the Hittite language had an Aryan base. He gives the example of the word 'khatti' which in Hittite may possibly be connected with Sanskrit 'kshatriya' and Pali 'khattiyo'. The intercourse between Hittite and India, however interrupted and brief, was important in that the knowledge of iron, which the Hittite show before other people was acquired by India. This could have been a two-way process, as is evident from the presence of the Indian humped bull on Hittite seals.[16] As far as Iran was concerned, Indian gods Indra, Varuna and Mitra were worshipped before Zoroaster, and only Agni, the Indian god of fire, remained common. Avesta also mentions the Land of Seven Rivers.[17] The Mohenjodro civilization was in close contact with these areas and had developed town planning, geometry, a basic system of counting, weights, scales and other subjects.[18] What was the influence of this civilization on latter developments? This is required to be explored.

The three earliest civilizations of Egypt, Mesopotamia and the Indus had a common factor—they were the 'earliest Riparian Urban Cultures and were centred round river's flow through the deserts', and they show many parallel developments.[19] In other words, the contact of India with Egypt, Mesopotamia, Sumeria, Iran and central Asia and later Greece was a continuous one since antiquity through trade, exchange of scientific knowledge, and cultural interactions. During the medieval period this interaction was further developed. The degree of interaction and the consequent diffusion of knowledge within the Asian culture area can be visualized by the remarks of Ibne Sina in his biography. According to him, when he wanted to learn mathematics, his father asked him to go to a particular vegetable seller to learn Indian mathematics. This indicates both the extent and level of diffusion of knowledge when even a vegetable seller could become an expert and teach others. In other words, it represents a *culture area,* where the flow of ideas and knowledge was a part of social, cultural, scientific and technical evolution.

Incidentally, this continuous interaction and the linkages were disrupted through colonization, when Indians began to look at these areas through western studies and points of view. Direct linkage was reestablished after India achieved independence. A large number of Indians have gone to and many have even settled in the countries of Arabia and Iran (central Asian countries have achieved their independence only recently). The interaction of these countries with Indian developments in science and technology has thus begun. This is very similar to what had happened earlier when the Arab Renaissance was triggered by the translation of Indian scientific texts in Baghdad.

The Language of Science in India

The brahmanical writings, whether in science or technology, dealt with the abstract and hence gave an impression of being timeless. As Kosambi has pointed out, 'Most of the surviving Indian documents are overwhelmingly religious and ritualistic.'[20] The writers were not concerned with history or reality. There was, according to him, another reason for not developing history: in the village life successive seasons were all that mattered, and these showed, from year to year, little cumulative change and created an impression of timelessness.[21]

Another feature of brahmanical writing, besides the language, was the method of writing. If science is based on observation and putting the observed data together to draw a picture and inferences from it, the language is the means by which the picture is constructed and inferences drawn and expressed. So, what we have is a constructed world, and in this context what Max Harkheimer said is relevant, in so far as science is expressed in a language which also represents cultural and political construct:

> The ideological dimensions of science comes to light, above all in what science closes its eyes to.[22]

It may also be worthwhile to quote in this context the great Arab Sufi, Saint Ibne Arabi (born AD 1165, died AD 1240):

> All that is left to us by tradition is mere words, it is upto us to find out what they mean.

And the real meaning can be understood only in the context of the construct and the constructs built by later generations.

Language can be expressed in the form of prose, poetry, anagram, abbreviation, and in so many other ways to make explicit what it wants to convey, or to allude to it or to conceal the meaning from others (i.e. the uninitiated). In the latter form it can be a means of exercise of power of men over other men.

The particular form of expression of science in the brahmanical literature was *shloka.* To Al-Beruni, who was a foreigner but a critical observer, *shloka* appears to be a poetic form rather than a means of clear expression. He says:

> Most of these books are composed in *shloka*.... If the Hindus happen to get some book, which does not yet exist amongst them, they set at work to change into *Shlokas* which are rather unintelligible, since the material forms entails a constrained, affected style, which will become apparent when we shall speak of their method of expressed numbers. And if the verses are not sufficiently affected, their authors meet with frowning faces as having committed something like mere prose, and then they will feel extremely unhappy. God will do justice in what I say to them.[23]

D.D. Kosambi has something similar to say about writing in this manner:

> Mathematical and astronomical works put into karika form are merely memorized, but incomprehensible to the uninitiated because each number and operation is denoted by many different words which have other meaning in ordinary usage.[24]

As regards the use of words he corroborates Al-Beruni, who comments elaborately on the last dimension:

> The Hindus use the numerical signs in Arithmetic in the same way as we do. I have composed a treatise showing how far, possibly the Hindus are ahead of us in this subject. We have already explained that the Hindus composed their books in Shlokas. If, now, they wish, in their astronomical hand books to express some numbers of the various orders, they express them by words used to denote certain numbers either in one order alone or at the same time in two orders (e.g. a word meaning either 20 or both 20 and 200). For each number they have appropriated quite a great quantity of words: hence, if one word does not suit the metre you may easily exchange it for a synonym, which suits. Brahamagupta says: 'If you want to write or express it by everything which is unique as the earth, the moon; two by everything which is double, e.g. black and white; three by everything which is threefold; the nought by heaven; the twelve by the names of the Sun.[25]

Incidentally, Persian, Arabic and Urdu literature each gave each letter of the alphabet of the language a number, and expressed even sentences by adding up the numbers of different alphabets in the sentence. For instance 'Bismillah-hir-Rahman-nir-Rahim' was expressed by 786. In other words one could use numbers to express a sentence or a sentence to express numbers. This was probably adopted from India.[26]

Al-Beruni's comments bring forth two features of the language used. Firstly, poetic expression and the metre were major considerations rather than an explicit expression. And in the context of the society only the initiated could fathom the real meaning. Further, the interpretations could differ. This also brings out the significance of Ibne Arabi's comments, as well as the ideological content of science. The latter is also borne out by another comment of Al-Beruni:

> They are by nature niggardly in communicating which they know, and they take the greatest possible care to withhold it from men of another caste among their own people, still much more, of course, from, any foreigner.[27]

The question which now arises is: Was Al-Beruni prejudiced? That Al-Beruni was not prejudiced would be evident from his acknowledgment of the advance made by the Indians in mathematics. The method of writing which developed was aimed at restricting the knowledge to only those with whom they wanted to communicate and to those they would initiate into the intricacies of the language as well as the meaning and the content of the knowledge.

If one thinks of the possible reasons for Indians adopting *shlokas* for writing scientific texts, then there appear to be two possible explanations: firstly, since paper technology was not developed in India, the only possible way of communicating knowledge was through oral means, by memorizing the text. Poetic forms are easy to remember. Secondly, the caste structure as it was developed in India confined the knowledge to the Brahmans and it was up to them to teach it to others. In every society this practice of withholding knowledge from the people was part of the political policy of the ruling class.

Another feature of the oral education system was linked to initiating the students to methods of computation, to mathematics and astronomy, rather than familiarizing them with various concepts and their significance. And thus this method may have come in the way of innovative development. This dimension is also brought out by Al-Beruni when he quotes Brahamagupta on different texts of astronomy.[28] He quotes Brahamagupta and says, 'Though the Siddhantas are many, they differ only in words, not in the subject matter. He who studied them properly will find that they agree with each other.'[29]

Another question which is significant is whether the scientists in India knew of contemporary developments elsewhere and what was the nature of the impact on them. For example, was Bhaskara aware of Al-Khwarizi's work on algebra brought out in AD 810? There was, as the evidence suggests, considerable contact through various channels within the culture area.

This form of expression leaves out the interconnections and linkages of knowledge with other human activities. Other records also do not throw any light on this aspect. Further, though we have some idea of the individual scientist's contribution, his linkages with his contemporaries, predecessors or successors are not known. Consequently, one is not able to develop a picture of successive developments.

Science, Society and Interaction

We are aware also as to what the relationship was between the development of mathematics and the needs of the State with regard to the very elaborate revenue and tax systems, and the problems arising out of inheritance and division of property, town planning and architecture. While these needs might have provided the initial impetus, further development might have been a matter of subject development. The linkage is, however, important. According to Kosambi:

> The moon with its phases sufficed for the primitive man's simple ritual.... This left the indispensable heritage of the lunar month, and prognostication by omens. The food producer's year is solar, which requires constant adjustment of the lunar months. The

> urgent need for a working Almanac lay at the root of astronomy, algebra, theory of numbers, all of which were conspicuous Indian specially Brahman achievements.[30]

While writing of the text leaves many such questions, the practice of knowledge in everyday use brings out interconnections and linkages. Early life in the country was centred around agriculture and its needs, as already mentioned. Subsequently, this led to the development of astronomy and later of astrology, when it was thought that planets affected human life and their positions could be used for making predictions. The planetary positions were for purposes of recording births, marriages, deaths and other events. Apart from such needs, the rich and the kings wanted to be sure of the success of their actions and to give the necessary confidence they looked for auspicious times. The kings had possibly another purpose as well—they wanted to use astrology to impress their subjects that their actions had been ordained by gods and had their blessings, and consequently, they were necessary and just. The seasons also dictated the type of diet to be used, the period of collection of herbs etc. The practice of yoga was part of the training of voice and body for music and dance. The list can be long, However, the point which needs to be considered here is how far these practices led to further development of the subjects and their theoretical understanding, and how these in turn changed cultural values.

Use of knowledge in every day life brings to surface another dimension: use of science for purposes of power to control the people. The educated elite, who develop abstract knowledge, use principles and laws and the rationality based on it for their own purposes; on the other hand, for the common and uneducated people, they develop and propagate myths, dogmas, superstitious beliefs, and the mantras to make them conform. This duality of beliefs in a society creates its own problems. The social and cultural pressures by the uneducated masses has its impact on the rationality of the scientists. History is full of names of scientists who were prosecuted for promoting a common rationality. In India, the lack of availability of works such as those of Ajita, Charvaks and Uddalaka indicates the failure of rationality based on the study of nature and the conclusions drawn from it.[31]

When Al-Beruni came to India, he looked at Indian science differently, in the context of validity and rationality of science as developed in the Islamic culture area; and he noticed the social pressures generated by the masses, as a part of different beliefs, which tended to be part of the scientific knowledge of the period. And in this context he says:

> Therefore, you mostly find that even the so-called Scientific Theorems of the Hindus are in a state of utter confusion, devoid of any logical order, and in the last instances always mixed up with the silly notions of the crowd, e.g. immense numbers, enormous spaces of time, and all kinds of religious dogmas, which the vulgar belief does not admit of being called into question. Therefore, it is a prevailing practice among the Hindus *jurare in verba magistri*, and I can only compose their mathematical and astronomical literature, as far as I know it, to be a mixture of pearl shells and sour dates, or of pearls and dung, or of costly crystals and common pebbles. Both kind of things are equal in their eyes, since they cannot raise themselves to the method of scientific deductions.[32]

Al-Beruni may not have fully realized the intermeshing of scientific thought and religious philosophy and social and cultural dimensions of science in India, as it was embedded and used in the maintenance of social structure, but he does not appear to be prejudiced, as he often acknowledges the advances made in India. The scientific tradition which he had acquired was an extension of Indian framework of observation and the Greek logical and philosophical framework which excluded myths and other common beliefs. It was based on a consistent rationality of its own. His critical remarks were directed against the acceptance of common beliefs and their incorporation within the framework of science.

The mixing of scientific facts and theories with the non-scientific due to religious ethos of society and social pressure of forces, which did not share the rationality of science, could be inferred from such facts as the rejection by the great astronomer Lalla of theories and concepts of Aryabhatta, since they were not in conformity with Brahmanical ideas then prevalent. Further, this is also evident, as Al-Beruni points out, from the duality in the approach of Brahamagupta, who on the one hand accepted the Rahu-Ketu theory of eclipse and, on the other, carried out investigations to work out the diameter of the moon to explain solar eclipse. Was the former approach to please the Brahmans and the latter to believe in and pursue his scientific investigations?

Actually, this phenomenon is common to all cultures in every period. The political and social pressures exerted by the people, who are uneducated and do not share the rationality of science, are exploited to dilute the content of science or to attack science whenever its conclusions come in conflict with the prevailing philosophy, the political interests or the social and cultural features of the elite. This is very much in evidence in contemporary society, including those of the so-called scientifically advanced countries.

A number of Al-Beruni's remarks have been presented here to give an idea of the perception of Indian science by a new culture, which arose as a result of Arab Renaissance. The Renaissance itself owed much to the translation of Sanskrit and Pali scientific, medical and philosophical texts, on the one hand, and to the translation of religious texts and literature on the other. Further, Al-Beruni's remarks are also important for the reason that these might have been a source of understanding for the many scholars who were to come to India to seek the patronage of the kings who had begun to establish kingdoms in India. They found that Indian science was totally integrated with the philosophical, religious and mythological views. In other words, science had a different meaning as compared to the science which was taught to them and whose conceptual and theoretical framework was different from the one they found in India. They further noted that in Indian science there was no distinction between the natural and the supernatural, both being the interplay of gods, and their concepts of time and space were also rooted in these ideas. The migrant scholars also noted the difference in context, form and method, as is evident from the various remarks of Al-Beruni.

Development of Sciences Before the Coming of Immigrant Scholars

It may be worthwhile to get an idea of the development of science in India before the coming of immigrant scholars, who wrote in Arabic and Persian. An understanding of this literature is necessary if a comparison is to be made with the literature produced after the establishment of the Sultanate and also to understand the nature of interactions that took place.

The literature available is so extensive and the issues are so well researched, unlike the Arabic and Persian literature written in India, that it may not be possible to go into details. Therefore, we will confine ourself to a few salient points so as to present here a comparative understanding of the common points and differences of the literature produced later.

One of the features of the scientists of the period was that they were astronomers-cum-astrologers as well as mathematicians, and they used the knowledge for both religious and secular purposes. The leading astronomer-mathematicians of the period were Sridharacharya (AD 991), Sripati (AD 1039-56), and Bhaskaracharya-II (AD 1150). Sridhar and Bhaskara had discovered a method for solving quadratic equations. Sripati wrote a treatise on mathematics, *Ganitatika,* wherein he dealt with permutations, combinations, proportions, notional places, etc. He had also written books on astrology, *Joyotisaratnamala,* and astronomy, *Siddhanta Sekhara.* In the latter text he followed Brahamagupta.

Bhaskaracharya-II was the most important mathematician and astronomer. His books on astronomy were *Siddhanta-Siromani* and *Goladhaya*. In these books he elaborated ideas on revolution of planets and other aspects. In mathematics, his two most important works were *Lilavati*, which was translated at the suggestion of Akbar by Fyzee, and *Bijaganita*, which was translated by Ataullah Rashidi at the instance of Shahjehan. These books covered theory of numbers and differential and integral calculus. Mention may also be made here of Aryabhatta-II and his *Mahasiddhanta*. These savants were followed by several other astronomer-mathematicians and a large number of commentaries were written on their works.

Volodarsky ranks Bhaskara at the same level as Aryabhatta-I and Brahamagupta. According to him, 'As a lucid expositor of abstract mathematical and astronomical rules, he was probably unrivalled among his class in ancient and medieval India.'[33]

Further, Bhaskara's algebra is characterized by the anticipation of the modern theory concerning the sign convention, and the use of letters to denote unknown quantities. His cyclic method of solving the Pellian equation was described by Hankel as 'the thing achieved in the theory of numbers before Lagrange is due to him. Bhaskara-II's *Tatkalika* method of analysis contains germs of modern calculus.'[34] Mention may be made here of astronomical instruments of Bhaskaracharya-II. He lists, according to Yukio Ohashi,[35] the instruments mainly the *Gola nadi valaya, Yaste, Sanku, ghati, Cakra, Copa, turya, phalaka,* and *dhi*. Further, Ohashi says that the first eight instruments are common with previous siddhantas of Brahamagupta, Lalla and Sripati. Major developments in regard to instruments took place in the fourteenth century, mainly by Mahendra Suri, the astronomer of Feroz Shah Tughlaq, and Padmanabha when the first Sanskrit works on astrolabs appeared.

The two major systems of medicine prevalent in India before the advent of Unani medicine were Ayurveda and Siddha. The first major works which were extensively used during the period (though written earlier) were *Charak Samhita, Susrut Samhita, Bhala Samhita* and *Stangahrdaya*. A number of commentaries were written on them. The major physicians of the period were Sivadasa and Chakrapanidatta (eleventh century), Arundatta and Nityananda (thirteenth century), Chakrapanidatta's important work is the commentary on *Charak Samhita* and *Susrut Samhita*. Nityanatha is significant in view of the fact that his work *Rasaratnakare* mentions opium. The Siddha system became more popular in south India and the works dealing with it cover both medicines and chemical preparations. Both Ayurveda and Siddha systems were basically philosophical systems, apart from treating the patients. The basic philosophy of the Siddha system was the development of drugs which would stop the decay of the body. According to it this could not be achieved through herbal drugs which themselves tend to decay; hence it recommends preparation of drugs from mineral sources. In this system, mercury and sulphur played a major role, separately as well as in combinations.[36]

A number of treatises were written on horses and elephants. An important text of the thirteenth century on Indian fauna was written by Namsadeva and was entitled *Mrganaksisastra*. Another important text of the thirteenth century, entitled *Saranghara Paddhati* by Sarangdhara, covers the plants of the country, and includes agriculture as well.

The physical world view was built around religious philosophies and schools of thought within them. To accentuate differences, each system developed its own physical and metaphysical thought and framework of knowledge. Within each system there was considerable scope for elaboration of concepts and ideas. However, despite these differences, there was a good deal of commonality. The commonality lay in recognizing both the heterogeneity of natural phenomena and the search for basic elements in the foundation of nature and the laws which cover natural phenomena. With regard to the former, the theory of five elements was developed, which combined both matter and qualities. In categorizing these elements, attention was paid to both the observable and the non-observable.

Matter was supposed to be composed of atoms, whose attributes depended on the philosophical system in which various ideas were elaborated. There ideas included, for example, the concepts formulated by Kanada and Jain philosophy.

The concept of motion was basic to the idea of nature, and it was considered as a factor of both creation and diversity as well as destruction. Many causes of motion that were developed considered it as of temporary nature, i.e. non-eternal.

The concepts of space and time were a part of the physical concepts. *Akasa,* though a part of the five-element theory, was considered, unlike the other four elements, as eternal and also non-material. Various interpretations of *akasa* appear to indicate that the concept was similar to the theory of ether in physics. The concept of space was developed to provide a positive location to material objects—whether static or in motion. Concepts of time were linked with changes—of seasons, movements, and concepts of past, present and future. There were considerable differences in the concepts of time; for example, the Buddhists denied the objective existence of time (construct of mind) while the Jains did not consider it as all-pervasive, though they found it eternal.

Having discussed some of the features of Indian science, it may be worthwhile to briefly mention the framework of science in India and its logic. The framework differed. The school of natural philosophers—the Charvaks, Lokayatas and Nastiks—specialized in the study of natural phenomena and drew their conclusions from their observation. They used logic to organize data and to sift it with a view to form a coherent picture of nature.

The other tradition was, by and large, built around the study of language, the proper understanding and mastery of which was considered a prerequisite for the study of science. Language was thus critical as a tool of logical analysis. The development of logic and the grammar of language were closely associated, and formed parts of the method of argumentation in science as well as in religious matters. The stress on subtlety, drawing minute distinctions in the language, was a characteristic feature of the scientific literature.

It may be mentioned here that the philosophical dimensions and the underpinning of scientific thought and literature came from Vedic literature. This was irrespective of different schools of thought and religious philosophies. The latter may have differed in social features, but the practitioners of science and the custodians of religion were the same—the Brahmans. They represented the educated elite and dominated socially. This was reflected in the remarks of Varahamira, 'What then are we to say of Brahman, if he combines with his purity the height of science.'

This very general and broad outline of Indian scientific tradition would be helpful in comparing the framework of science which came with the immigrants, based on Greek philosophy, and their own contributions based, by and large on Aristotelian logic. This is vital for understanding the nature of interaction which would be discussed later.

III. NATURE OF SCIENTIFIC LITERATURE IN ARABIC AND PERSIAN PRODUCED IN INDIA

Before discussing the question of interaction, it may be worthwhile to briefly indicate the character of science which came to India with the scholars from Arab countries, Iran and central Asia, seeking the patronage of kings.

These scholars were quite aware of scientific developments in India through the works of Al-Beruni and others, particularly in mathematics, astronomy and medicine. They had also absorbed the Greek scientific tradition by studying Greek texts, their translations, interpretations through commentaries, and analysis of problems. The characteristic features of their literature were:[37]

1. using of unambiguous and refined language;
2. providing definitions of the terms used;
3. posing problems and providing their solutions;
4. giving examples for the students/readers to solve;
5. displaying Aristotelian logic and rationality based on Greek philosophy;
6. displaying the threefold purposes of knowledge—religious needs, agricultural requirements, and everyday needs of life—imparting to it a utilitarian character;
7. quoting authorities, acknowledging works of predecessors, discussing different points of view and presenting views for or against a theory;
8. extending the base of knowledge to cover newer areas like (a) geography, (b) geology, gemology and related instrumentation, (c) detailed knowledge of animals and plants, (d) physics especially optics, specific gravity, magnetism, and concepts of motion and time, and instruments for measuring time;
9. compiling catalogues, Zijes, checking tables and developing instruments for the purpose;
10. translating Sanskrit texts and familiarization with and adopting many features from Sanskrit traditions; and
11. considering religious and other opinion often coming in the way of and suppressing scientific opinion.

Haji Abdul Hamid (fourteenth century) wrote his book, *Dastur-i-albab fil, ilm-al-hisab* (1333-58) comprising five chapters, the third chapter of which is missing from the Aligarh collection.[38] He divided science into two sections: (a) *I'Imul Adyan* (i.e. science of religion covering theology, *fiqah, Hadis* and observance of religious practices and personal law) and (b) *I'Imul Abdan* (i.e. sciences). He clearly indicates the use of sciences for purposes of religion, like the use of mathematics for calculating *Zakat* and *Sadqah,* of geography for finding the direction of *Qiblah,* and of astronomy for working out the calendar and timing for prayers.

He gives twelve references of earlier works. The manuscript spans a large number of areas covering weights and measures, including the Indian system; tables of multiplication including the multiplication of fractions; tables relating to property, farming, arts and crafts; and units of space and distance. The book also provides examples and methods relating to accounts, taxes and fines, land-grants and landed property, land measurement, salaries and scholarships, remunerations and rewards, etc. In other words, its contents cover almost all practical problems. Further, by separating the religious science, as did Descartes later, Abdul Hamid could deal with various problems without delving into religion or religious arguments and could discuss them in terms of their definition, method and logic. In fact, the most interesting part of the book are the following few couplets:[39]

Whenever I examined sciences through
In *Nav* (literature) and *Fiqah* (religious science) also there are differences
There is no agreement between two persons on one point
O *Muharrir,*[40] mark, I told you
In controversial matters, there is difference of arguments
On that specialty, everyone said something different
In mathematics I did not find controversy from any one
I tried very much but could not see
This is established by conviction based on proof
Watch out so that it may not be thrown out to rigmarole

These couplets are interesting from many points of view and provide us with an insight into the mind of the author on the one hand, and throw some light on the times he lived in, on the other. Any book which deals with mathematics only subject-wise is sure to miss out on this dimension, brought out by this couplet.

The question arises as to what was the need for the author to say so? The fourteenth century must have been a period of intense debate and controversies in the arena of religion. Abdul Hamid, a devout Muslim being a Haji, probably wanted to distance the sciences from religious controversies, and in doing so he was perhaps attempting to secularize science. The latter dimension is more probable, as he had separated religious sciences, *I'Imul Adyan* from natural sciences, *I'Imul Abdan.*

Abdul Hamid was not alone in promoting the secular dimension of science, as we find later in the same century, Mirza Ulugh Beg, the king at Samarqand, whom Jai Singh referred to as a peace-loving Sultan[41] said something similar:

> Religion disperses like mist, kingdoms are destroyed but the work of the scientist remains forever.[42]

Obviously something significant was taking place in this century, in this culture area. Was it an attempt, after delinking science from religious philosophies and practices, at giving science a wider base outside the narrow confines of religious groups? The culmination of this attempt was in the efforts of Jai Singh in the eighteenth century when he tried to integrate the Islamic, Indian and European traditions in astronomy.[43]

Another feature of the couplets is that they bring out the differences in the use of language: the language used in religious affairs could be interpreted differently by different people, while that used in mathematics had no such possibility.

Finally, the most important dimension is brought out in the last couplet, that is, it is not just belief, but conviction based on proof that is important. While matters of religion are matters of belief, mathematical solutions are based on proof. He warns the reader that these may not be thrown out in disputation and rigmarole. This may be a reference to the controversies of the period, when science and scientific theories were being scrutinized to find out whether they were in conformity with religious texts and rejected if they were not.

A manuscript of the sixteenth century, *Saba Samavat*[44] by Fathullah Farooqi, written during the accession of Akbar to the throne (i.e. 1556), is an interesting document. It is a mixture of astronomy and astrology, of both Islamic and Indian traditions, and seems to be aimed at providing information on a number of subjects based on Indian tradition: the effect of stars on the temperament of children and their future; selection of time for marriages; choice of period for construction of houses; time for sowing and other information about agriculture; measurement of land and descriptions of various units used. In addition, it provides methods of finding the duration of day and night in different seasons; causes of solar and lunar eclipses; and causes of earthquakes, which are linked with the astronomical phenomena. The conceptual framework of astronomy is Ptolemaic, but efforts appear to have been made to incorporate Indian terms, concepts and framework while mentioning various dimensions of astronomy-astrology (e.g. Zodiac signs, units of horoscope, spheres and mansions).

In addition to linking astronomy and astrology to the above mentioned areas, it covers a wide range of information on geography, physiology, anatomy, humours, fevers, properties of foods and even directions for keeping accounts.

The book uses simple language and gives definitions of terms used, both in Persian and Arabic as well as in Sanskrit. It appears to be aimed at providing knowledge to the people, useful in everyday life. Further, it tends to correlate diverse phenomena, such as time of birth, effect of seasons on temperament, as well as the effect of seasons on different diseases, agriculture, house building and natural disasters. In short, it is a book which seeks to put together all available knowledge for the education of the people.

Another text, *Jawahar-Ul-Ulum Humayuni*[45] by Mohammad Fadil-bin Ali-bin-Mohammad al Miskini al Samarqandi, was written during the reign of Humayun (1530-58) and was dedicated to him. The name of the book when translated into English would be 'Pearls of the Sciences'. This encyclopeadic publication covers a wide range of subjects and aims at providing the then available knowledge to people in one volume.

It has a long chapter on the geography of India, giving the borders of India, its division on climatic lines, and an indication of densely populated areas. It lists twenty-seven types of minerals, corals, glass and stones, gives some idea of their features to enable one to recognize them, and indicates their medicinal properties.

There is a long chapter on hawks, their characteristics to enable one to differentiate one variety from another, their diseases and cures. The chapter on different animals and birds describes, as usual, their characteristic features, methods of reproduction, their habitats, and their curative and other properties. Interestingly, it covers birds and other animals found only in India, but also mentions the giraffe and ostrich, found only in Africa.

There is a chapter on anatomy and physiology, which lists various bones and parts of the body and their descriptions. There appears to be some effort at classification, primarily on the basis of function (e.g. sense organs, food organs, genitals, etc.). It also divides spirit as vegetative, animal and vital. It puts together the then available knowledge on human temperament, effect of seasons on the human body, general principles and guidelines on hygiene, and methods of regulating life. It gives details of different diseases classified as diseases of different organs and methods of curing them; a brief idea of different drugs, categorized on the basis of functions they perform, and methods of preparing them; qualities of different foods, categorized as hot and dry, cold and dry, hot and moist, cold and moist, and the manner in which each type affects the various parts of the body.

The chapter on astronomy is a summary of known knowledge within the framework of the Ptolemaic system. An interesting feature is the argument to prove the roundness of the earth. The chapter on mathematics covers arithmetic and geometry, giving definitions and guidelines for calculations. It also gives directions for keeping accounts and briefly covers optics and alchemy. In short, it is a general purpose book—a guide for the layman.

I shall briefly mention the manuscript, *Nuskha-dar-Fann-i-Falakat*[46] by Amanullah Husaini, son of Mahabat Khan, a noble in the court of Jehangir. It is a book on agriculture. It contains information on crops, different types of vegetables, fruit trees, flowering trees, herbs, various kinds of seeds, etc. It gives directions about the choice of seeds, land preparation for sowing different crops, methods of protection of different crops, different kinds of manures to be used for different kinds of crops, and methods to increase the crop yield. It lists different types of diseases of agricultural and other plants and methods to check them. The book also provides a summary of climatic conditions in different parts of India and information on different types of crops, vegetables fruits, spices and trees indigenous to India, grown in each climatic region and the practices followed by local farmers.

There are also some special texts, such as those on instrumentation. *Ruba Mujaiyab*[47] is a book on astrology but also provides directions for making instruments to find longitude and latitude, direction of *Qiblah*, and many other astronomical phenomena. Incidentally, it also gives auspicious and inauspicious signs. It gives Sanskrit equivalents of Arabic terms. It was written by Ataullah Qari during the reign of Burhan Nizam Shah of Ahmadanagar (1508-54).

Another work on instrumentation is *Kashif-ul-Hijab-Fi-I'Imul lusturlab,*[48] written in the seventeenth century (1679) by Abul Hasan bin M. Baqar bin Ghayasuddin Ali Al Husani. It is a comprehensive treatise, a sort of manual, describing the origin of the word *ustarlab* from Greek. It mentions different types of *ustarlab,* including those used for northern and southern hemispheres. It also describes different parts of the instrument, and their functions and methods of using it for different astronomical and geographical purposes, besides finding the direction of *Qiblah* and making horoscopes.

In addition to the special books by scholars, there is another major source of information: the chronicles and memoirs of the kings and histories of the period. To mention a few, *Sirate-Feroze Shahi*[49] presents information on the practice of medicine, anatomy, physiology, pathology, therapeutics, establishment of hospitals, astronomy, astrology, irrigation projects, and other public works undertaken; Tas Gharyal (1370) presents a most interesting description of a clock, besides describing the transfer of a stone pillar to Firozabad (Delhi); *Ain-e-Akbari*[50] is a mine of information both on science and technology;[51] and *Tuzuki-i-Jehangiri* is another on natural history. Travellers' accounts like those of Ibne-Batuta are another source of information.[52]

Mention may also be made here of Fathullah Shirazi, a theologian from Iran. When he came to India and attended the court of Akbar, his genius came into full play as a mechanical engineer, a mathematician, and an astronomer, besides contributing to philosophy, medicine,[53] grammar and literature. In other words, there was hardly any field to which he did not contribute. According to Abul Fazl, 'If the old books of wisdom had disappeared, he could have laid a foundation of knowledge.'[54]

Shirazi worked with Toudermal to check State accounts and reform the system. He also examined the currency and found discrepancies in the rules governing coins which became short of weight on account of their excessive use in circulation.[55] In doing so he must have calculated the loss of weight against time, and may have developed some statistical ideas.

Mulla Mahmud Jaunpuri (1585-1651) wrote a number of books. His *Al-Danhatul-Maiyyahdafi-Hadiquatis-Sural Wa-Maddah*[56] deals with physics—matter, form and motion, concepts of time and space, gravity, etc. A cursory glance at the text shows logical analysis of different points of view, the nature of opinions and conjectures of different authors, an endeavour to contrast these with what is observed, and deductions made from the latter.

Jaunpuri's major work is *Shams-i-Bazigah*, in two volumes. The first volume comprises three parts; the first deals with time and space, motion, numbers, etc.; the second with heaven and earth; and the third with cosmology. The second volume deals with the Ptolemaic system and some of the problems it raises.[57] He also discusses the nature of moon spots. According to Abdi:

> Mulla Mahmud Jaunpuri's remarks and subsequent observations by others led Mirza Khairullah Khan Muhandis, an associate of Jai Singh, to declare in his commentary on *Zij-e-Muhammad Shahi*: 'We have found the orbits of the sun as well as those of all the different, elliptical forms... when the equations are derived taking the orbits elliptical and calculating the positions, they generally conform to observation.'

It may be noted that this remark is based on observation only; and there is no evidence that Khairullah Khan had any knowledge of Kepler's theory.[58]

IV. NATURE OF INTERACTION

The above brief and indicative description of a few texts would have given an idea of the state of scientific work and concepts during the period. The authors who wrote those scientific texts also contributed to literature, philosophy and theology. However, the main point to be emphasized here is that the language of the scientific texts and that of other topics differed. The religious ethos which dominated the period also influenced these authors in looking at texts and materials, as is evident from the various remarks of Al-Beruni; for example, when Firoz Tughlaq got Varahamira's *Brhat Samhita* translated into Persian: 'It was felt that eight chapters were not in conformity with the principles of Islam so they were omitted in translation.'[59]

The question of interaction of Sanskrit scholars and literature with Arabic and Persian scholars and literature requires examination. This has to be done for each field of science. In mathematics, as mentioned earlier, the Arabic and Persian scholars were quite familiar with Indian literature.

Akbar got Bhaskracharya's *Lilavati* translated into Persian to enable people to know rules of arithmetic. But W.H. Abdi pointed out[60] that 'somehow *Lilavati* could not become very popular' while *Khulasat-al-Hisab* of Bahauddin Amili was used as text. He further stated that 'There does not appear to be much interaction between western and central Asia and India in geometry. Probably the reason was different approaches.' According to Abdi, 'Geometry in ancient India was basically constructional, it arose and developed with needs of rituals and cosmographic speculation.'

Tahrir Uglidis remained the most important text for Arabic- and Persian-reading scientists. Lack of development of Algebra is significant during this period. Even though Umar Khayyam's poetry was known, algebra did not attract much attention. According to Abdi 'Ulugh Beg's *Zij* which remained for a long time the main source of astronomical computation was translated into Sanskrit under the supervision of Akbar's scientist minister, Fathullah Shirazi, with the help of Abul Fazl. Kevalrama Srimal's *Tara Sarini* is in fact a Sanskrit translation of *Zij-i-Ulugh Beg*. Besides the *Zij-i-Shahjehani*, there is a manuscript entitled *Zij-i-Nityanandi Shahjehani* in the Maharaja of Jaipur Museum, prepared in Sanskrit by Nityananda, son of Devdatta, the scribe being Gangarama.'[61] Further, 'in preparing different tables scholars could not avoid drawing on Sanskrit text, as is evident from the works of astronomer mathematician like Ghulan Husain Jaunpuri. However, this interaction could not evolve any unified principle of astronomy in India during the medieval period.'[62]

The interaction in the field of astronomy has been well summed up by S.N. Sen:[63] 'In the wake of introduction of Arabic and Persian astronomical traditions into India under State patronage, there arose an effort, on the part of Hindu astronomers, to produce translations, adaptations and books of combined tradition, the combination taking mostly the form of mere addition, explanation of one through the other or regular coalescence.' This led to writing of bilingual dictionaries and Sen lists a number of them. Further, he says, following Al-Beruni, 'There had been sustained effort to translate Arabic and Persian texts into Sanskrit. These texts included those belonging to the schools of Maragha and Samarqand, like *Zij* of Ulugh Beg *Jica Ulughbegi*, and al Qushji's *Risala dar hay'at* in *Hyatagrantha*.' Sen also lists a number of translations covering *Almagest* and *Tahrir-u-Uqlidas*. The same interaction took place in developing astronomical instruments. According to Sen, 'With Arabic astronomy came astrolabe (Arabic "usturlab", Sanskiritized into "ustarlava").... As the instrument grew popular in the land it began to be inscribed in Devanagri script as well. The earliest work on astrolabe is *Yantraraja* (1370) by Jain Mahendra Suri, court astronomer of Feroz Shah Tughlaq....'

In the field of medicine there was close interaction between Ayurveda and Unani systems, perhaps because both the systems were based on similar principles. According to D.K.S. Chauhan and R.N. Singh, a number of drugs like *aphim* (opium), *gwarpetha, kesara madhkarni* (*khurasani ajwain*), *mastagi* and several others known to Unani hakims were introduced into Ayurvedic *Materia Medica* from the ninth century to the fourteenth century.[64]

A number of Persian and Arabic texts were used in Unani medicine (e.g. *Ganj-i-Budaward* and *Dastur al Hunud* by Amanullah Khan). According to S.K. Misra, B.R. Bhatta, P.S.N. Bhatt and R.B. Dwivedi:

> Thirteenth century Muslims learnt Indian languages and patronized the development of Indian arts and sciences. There was great interplay between the main medical

> literature that they brought with them and the existing Ayurvedic treatises. This is evident by the differences in the versions of Persian literature preserved in Persia and Unani medical literature written in Arabic by Indian Muslims. It was this period when the real harmonious interaction of scientific thoughts of the medical scientists from different disciplines took place and this is evidenced in the Ayurvedic literature created during this period like that by Sarigadhara and it was at this stage that the primary importance to the examination of pulse (nadi) was started, though there are Sanskrit manuscripts available attributed to 'Ravana, Agnivesa and Harita'. The effect of Unani medicine in the contemporary Ayurvedic thoughts and vice versa may be taken as positive evidence of the idea of integrated medicine during that period which is maintained till date amongst Rajasthan Vaidyas.[65]
>
> During the fourteenth century a manuscript was composed in Telengana by Muhammad bin Tughlaq (AD 1313), which contains forty-six chapters and the forty-first chapter is entirely on Indian sources for the calcination of mercury, gold, silver, copper, etc., taken directly from Nagarjuna and other yogeswaras.[66]

Another area where intensive interaction took place was the collection and documentation of information by the scientists from the local people, such as those in the area of fauna and flora.[67] Those who collected the information gave the names of the flora or fauna in Persian, Sanskrit, Arabic, Hindi or in other languages. This was found very useful in the case of herbs used in medicine, etc.[68] The same applied to the area of geology, mineralogy, metals or various arts and crafts.[69] The other type of information compiled was about animals, particularly the hunting animals, covering their physiology, anatomy, habits, habitats, food, diseases and their treatment, and breeding, including breeding of specific features. Such information was generally collected by hunters, hunting being a major sport of the period. For instance, Khwaja Muhammad Yusuf bin Muhammad Raza, Mir Shikar of Aurangzeb, compiled such information.[70]

V. CONCLUDING REMARKS

The period under consideration can be said to be a period of considerable social change, in terms of social mobility, particularly in the area of education and upward movement of lower castes.[71] This was probably due to the establishment of a large number of *madarsas*, which were open to all. The spread of education resulted in cutting across social barriers. The advantage of *madarsa* education was taken particularly by those who were denied any social status or education to better their lot. Ibne-Batuta, the Arab traveller, speaks highly of one Ratan, a barber by caste, who became a mathematician and rose to a high status, when Mohammad bin Tughlaq appointed him the Wali of Sind.[72] In fact, the aristocracy did not like the upward movement of people and complained of Indians, and what they called the low-born people, rising upwards and occupying high offices. For instance, according to Barani, in the last phase of Allauddin Khilji's reign, high offices were held by such people.[73] A similar situation prevailed in Gujarat and the Bahmani kingdoms.

The second feature of this period was, with the adoption of Persian as the court language and for keeping of records, a large number of Hindus learnt Persian.[74] Babur when he came to India found all revenue officers Hindus.[75] In other words the elite became bilingual. judging from the number of translations from Sanskrit to Persian, and the use of Persian for keeping accounts, records and court proceedings. Toudermal and Fathullah Shirazi worked together on the reform of the revenue system of Akbar, which means that both knew Persian: Toudermal may in all probability would have known Sanskrit as well. Shirazi also translated from Sanskrit to Persian, indicating his knowledge of Sanskrit. The author of *Tibbe-Ferozeshahi* as well as Miyan Bhowa, the author of *Ma'din-al-Shifa-i-Sikander Shahi,* must have had enough knowledge of Sanskrit. Large-scale translations of astronomical texts into Sanskrit, or the work of Mahendra Suri, the court astronomer of Firoz Shah, are indicative of bilinguality of the educated elite and scholars. Siddiqui mentions the instances of a Brahman by the name of Dunkar, who was a poet and scholar of both natural sciences and Muslim sciences, and of one Sheikh Abdullah born in a Hindu family and known for his Islamic knowledge.[76] On the other hand, a large number of translations from Sanskrit to Persian by Muslim scholars indicates their knowledge of Sanskrit. This bilingualism of the elite of the period has not yet been adequately explored.

The third feature of this period was a continuous pressure on the Kings from conservative Muslim ulemas to limit education to theological teachings and to enforce Islamic laws. While there was a strong opposition to rational science, there was a counter current to understand and promote rational sciences, particularly built around the study of mathematics, astronomy, medicine and philosophy. The case of Abdul Hamid Muharrir has already been discussed. Feroz Shah Tughlaq's interest in astronomy and rational sciences led to their development through the *madarsas* he established.

Siddiqui discussing the Lodhi period mentions the interest of Sikandar Lodhi in the promotion of rational sciences. According to him, 'He sought to overcome contemporary prejudices and investigated facts for himself in order to find out the truth.'[77] The king was interested in different schools of thought, he questioned the validity of age-old beliefs in case they did not appeal to reason.[78] Perhaps as a result of patronage of the king a number of nobles and scholars took interest in and promoted rational sciences. Siddiqui names a few scholars, like Azizullah who settled in Sambhal and introduced a systematic study of rational sciences, and Sami-ud-din Kambo who mastered rational sciences. Sikandar Lodhi's Wazir, Miyan Bhowa, was greatly interested in the sciences and humanism and his book *Ma'dan-al-Shifa-i-Sikandar Shahi* was based on the ancient Indian system of medicine.[79]

The same attitude is found in the writings of Moghul kings, who also resisted the pressure of conservative ulemas and promoted rational sciences.

The promotion of rational sciences, in whatever period and language, does not mean that people lacked religious, linguistic and cultural affiliations. They had all these linkages, yet they always tried to overcome and fight back the onslaught of conservative clergy, who wanted to limit knowledge to religious teachings. Indeed, there was always a zest for acquiring knowledge by observing, analysing and understanding natural phenomena, in terms of logic and philosophy, and this tendency often asserted itself with State patronage or quite often without it.

In every society, culture and civilization we notice the presence of two contrary movements and the struggle to dominate society. The conservative elements trying to control the growth of knowledge and the knowledge seekers endeavouring to broaden the frontiers of knowledge and thus providing humanity with a new understanding of phenomena and creating a new vision.

The fourth feature of the period was reflected in the personality of the scholars. Unlike today, when there is a high degree of specialization, the scholars of that period had multidimensional personalities, understanding and contributed to a number of areas. The areas were as diverse as religion, theology, literature-poetry, medicine, mathematics, astronomy-astrology, etc. The knowledge they had was used not only in their daily life but also to teach and guide others.

The case of Fathullah Shirazi has already been mentioned and need not be repeated. To give another example, let us take the case of Amir Khusro (thirteenth century), a nobleman and soldier in the armies of many kings, and a sufi disciple of Nizamuddin Aulia. He was also a litterateur and poet of eminence, and a great musician, who developed many ragas, invented the sitar (*sehtar*). But he was also well-versed in rational sciences. His knowledge was reflected in his poetry. For instance, in *Ijaz-i-Khusravi*, he indicated the centrality of the sun when he said:

> People move around the man in authority as the earth moves around the sun.[80]

This is both a satire on courtiers and a statement on an astronomical fact. About astronomy he further says in *Qiran-al-Sa'adain*:

> The movement of the earth has been linked with the time, hence the day and night, the seasons of spring and autumn. These changes constitute the source of life and comfort for the living beings.[81]

Apart from astronomy and astrology he was also knowledgeable about the achievements of scientists of ancient India. In *Nuh Siphar* he said that Hindus were well-versed in astronomy, mathematics, physics and divination of past and future.[82]

Amir Khusro was not only well-versed in the achievements of ancient Hindus, but also took great pride in them. He considered these as part of his heritage when he said:

> India is a land of many languages, which is the main reason for its glory. Since ancient times Hindi has been the language of common people in the north.... But there is another language that is so august among Brahmans, it is called Sanskrit from time immemorial...
>
> Knowledge and learning of the Hindus, concealed wisdom, and learned ideas in India were beyond calculation. Greece was famous for its achievement in philosophy, but India was also not devoid of it. Here logic, astronomy and dogmatic theology could be learnt easily.
>
> These three creations of India: Mathematics, Panchtantra and Chess are explained as expression of wisdom.
>
> My rival comes forward with taunt, why do you claim this superiority of India over all? One is that this is my heaven and mother land.[83]
>
> Wise people and scholars who seek help in knowledge are disciples of Brahmans.

Finally he said:

> Rightly speaking I am an Indian bird
> Ask of me Hindvi that I may sing in it.[84]

This commitment of Khusro to India, its heritage and the pride in its culture was also a beginning of a new culture, resulting from the intermingling of the two streams. Khusro was not alone; from Khusro to Dara Shikoh and Jai Singh we find a string of personalities who aimed at and prompted what later came to be called the composite culture of India, and more beautifully expressed as *ganga jamni culture.* In the creation of this culture, the sufi movement with its own unique ethos played a significant role. The sufi movement has been studied on the basis of *silsilahs* (i.e. various groups having loyalty to a specific guide). It is also categorized as *shariati* (i.e. those following *shariat*) and *tariqati* (i.e. those following tradition). Further, based on the temperament of the guide, they have also been categorized as *jalali* (i.e. those with hot temperament) or as *jamali* (i.e. those with sweet temperament). Joseph Needham[85] has classified them as *esoteric*and *naturalistic*, the latter being those who had interest in science and technology. In this category mention may be made of Jabir Ibne Hayyan, the chemist, and

Umar Khayyam, the poet, astronomer and mathematician. In India, perhaps Khusro, Kabir who worked as a weaver, and Mahmud Shah Musafir who built the underground water system and the Panchakki (water-mill) in Aurangabad, qualified as naturalistic sufis.

Irrespective of categorization, the main point which is required to be stressed is that, the sufis preached different ways of reaching god or arriving at truth, as against the shrill cry of *jehad* and its single way of reaching god. The former created a basis for developing a plural society. Thus, by undertaking projects to benefit the people, like the work of Mahmud Shah Musafir, or through the poetry of Raskhan and Rahiman or the writings of sufis like Sheikh Mohammad (who wrote in Marathi) a pluralistic cultural ethos could be created.

The question which now arises is how this ethos and interaction between Arabic and Persian scholars and Sanskrit scholars affected science and its further growth.

However, despite the general ethos of bilingualism and plurality and State patronage to promote interaction, through the support of both Sanskrit scholars and Arabo-Persian scholars, all that was achieved was the availability of translations and adaptation of knowledge of one stream from the other. Despite the many books that were written combining the two traditions, an integrated single tradition did not emerge to serve as a base for further development of science or for providing a new direction.

From the many probable reasons for the lack of further evolution of science, it may be worthwhile to mention the following:

1. During this period India remained an agricultural society and, consequently, demands on science remained the same and no new challenges arose to create new knowledge to help solve new problems. Only two major developments took place in the area of technology: first, introduction of paper technology made knowledge accessible to a wider section of society. Second, there was some development of military weapons technology, apart from development of arts and crafts in a number of areas. But these developments were based on practices, improved and developed through experience, and no basic or theoretical development took place.

2. The division between science and technology continued, despite the fact that artisans and craftsmen gained in social status. Scientific activity and knowledge, by and large, remained a preserve of the elite, while arts and crafts remained with the less privileged groups. A result of this division was that the problems generated by technology were not attempted by scientists to widen scientific knowledge and create a theoretical understanding of problems.

3. The pluralistic tradition of Hinduism, whereby different philosophies continued to coexist—the most rational as well as the mythological—and the pluralistic ethos created by sufism led to the coexistence of the two streams—Sanskrit as well as Arabo-Persian—without the emergence of any unified, integrated tradition. The latter process was also hampered by the continued domination of classical languages.

4. Religious prejudices and linguistic arrogance may have also come in the way of evolution of a single tradition. This was so despite the effort of many to overcome these limitations and boundaries.

5. The philosophic and theoretical framework being different—Vedic in one case and Ptolemaic, Euclidean and Aristotelian logic in the other—and both largely associated with religion, the pressure of conservative elements was too much to discard the overall framework in order to develop a new integrated tradition.

6. It also appears that two different processes remained at work during the period, one working towards integration of the two traditions and the other keeping them apart.

The counter to this liberal movement and sufi pluralistic tradition was led by conservative ulemas like Qazi Mughis during the reign of Allauddin Khilji and Maulana Abdul Qadir Badauni during the reign of Akbar. They were opposed to the sufi pluralistic and liberal tradition, and endeavoured to convert India into an Islamic State. Their counterpart was the insular Brahman steeped in the concept of his purity and the purity of knowledge, as would be evident from the remarks of Varahamira mentioned earlier and as quoted by Al-Beruni. Both the Mullah and the insular Brahman did not want to go beyond the Quran and the Veda, as they thought that all knowledge was contained in the sacred text and all that was required was to understand and interpret it.

These people were able to reinforce their base during times of political and social unrest, as people became more and more uncertain of the future. This happened because the elite failed to diffuse their rationality amongst the people at large.

7. In the absence of institutionalization of education, the continuity and accumulation of knowledge and expertise in specific institutions did not take place. Education being organized around scholars, with the death of the Master, the school often dispersed.

8. Frequent changes of dynasties and kings with different approaches to knowledge also came in the way of continuous growth of institutions and accumulation of knowledge around them.

Despite these factors, was there a possibility of India developing a unified base of science, incorporating new knowledge that was being produced in Europe? The literature of the period and the efforts of Swai Jai Singh do indicate that development in this direction was probable. However, whatever was left of the liberal pluralistic tradition and the growth of rational sciences, the possibilities which were emerging then were disrupted by colonization. The colonizer reinforced the conservative ethics and religious grouping of the people, and imposed a new scientific system in a new language, completely marginalizing and delinking the earlier knowledge system with the new. The irony of situation was that they used the knowledge as well as technology for the development of their system. But that is another story.

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CHAPTER II

Time in Medieval India

C.K. Raju

I. INTRODUCTION

In my opinion, time remains more important than space even after the theory of relativity. So, in this hasty summary, I will confine all but one of my remarks to time perceptions in India during the relevant epoch.

Medieval Ideas of Space

My only remark about space is meant mainly to illustrate that the medieval period in India was no analogue of the Dark Ages in Europe. Lacking the guiding hand of an infallible authority, learned men at least were quite at home with the idea that they lived on a spherical earth.[1] At the start of the epoch, Al-Beruni (a scholar commissioned by Mahmūd of Ghaznī to study India to support his invasion),[2] accurately (to within 0.25 per cent) computed the radius of the earth, hence its (meridional) circumference, using simple instrumentation, an elegant method, and a high-precision table of sines and cosines itself obtained using interesting numerical calculus techniques. In contrast, in Europe, Columbus did not have anything like such a precise estimate, and it was only towards the end of the seventeenth century, after Picard's observations, that Newton revised his earlier value of 17,000 miles for the circumference of the earth,[3] off by more than 25 per cent.

Time, Religion and Society

To revert to time, perceptions of time concern not only both cosmos and ethos, but physics, society, and morality. 'Morality' is perhaps a bad word. Time perceptions concern all the three relationships in A. Rahman's apt summary of 'Man's relation to Nature, Man's relation to Man, and Man's relation to himself,' though the 'himself' in the last relationship might have been called Man's relation to Rahim or Rāma during the period under consideration, so that it perhaps ought to be capitalized!

This needs some elaboration since it is not the way in which most people conceive of time. More taxonomically, time concerns (a) the nature of the cosmos: e.g. creation, recurrence, apocatastasis; (b) hence, eschatology: e.g. life after death in successive worlds, in heaven or hell; (c) ideas of determinism, 'human freedom' etc., which we would today regard as related to the structure of time, but which were then regarded as related to the powers of God or gods or kings; (d) cause: e.g. the cause of rebirth or of suffering; purpose: e.g. to achieve immortality, or to end suffering; and 'mechanism': *tariquā,* meditation, the Way to achieve this purpose; and (e) the nature of reality: e.g. whether ephemeral things can be real. As such, the nature of time does concern key aspects of the entire religious philosophy of that period.[4] 'Cause' also relates to social organization through the distribution of credits by cause. This is too vast an area, which I will not attempt here to cover systematically.

The Physical World-View

The physical world-view helps to focus one's thoughts. The physical ideas of time during the relevant period, in the relevant region, can be summarized in two words: (1) quasi-cyclicity, and (2) Grace.

Quasi-cyclicity of time refers to the idea that human beings are reborn in successive worlds that approximately repeat. This idea ought not to be confused with the Stoic idea of eternal or exact recurrence, as Augustine, perhaps deliberately, did. As an example, this idea of quasi-cyclic time provides the physical basis for the Upanishadic notion of *ātman* underlying the Advaita Vedānta, as I have explained elsewhere. As another example, a related idea of transmigration and deliverance (*hūlul, ittihāda*) can be found amongst the Sufis, for example in the poetry of Jalal ud Dīn Rūmī:[5]

> I died as mineral and became a plant,
> I died as plant and rose to animal,
> I died as animal and I was Man.
> Why should I fear? When was I less by dying?
> Yet once more I shall die as Man, to soar
> With angels blest; but even from angelhood
> I must pass on. . .

With this world-view, the primary teaching is to achieve deliverance (*mokṣa, fanā*) from the world, through a process of spiritual purification. The poem continues, citing the Ku'rān (II. 151):

> Oh, let me not exist! for Non-existence
> Proclaims in organ tones, 'To Him we shall return'.

Grace refers first to the idea of ontically broken time: that there need be no absolutely definite connection between one instant and the next. (This is another idea that has been badly mauled in western philosophy since Aquinas, for reasons explained below.) As an example, we have al-Ghazālī's teaching, accepted by both Sufis and orthodoxy, that the world is continually created every instant (time-atom) by Allah. Any causal relations between one instant and the next are not necessary but only habitual: Allah creates things in a conventional sequence, but is not compelled to do so. As another example, we have the idea of miracles in the more naïve forms of popular Bhakti: there is no causal necessity, for a deity may transcend the humdrum sequence of cause and effect. With this world-view, the Sufi and Bhakti teaching is to shun the momentary, and to fix one's sights on the eternal, union with which is to be obtained exactly as one would arouse the Grace of a personal deity through love, devotion, humility, music, or harmony. There were those like Ma'rūt al-Karkhī (*c.* 815) who went a step further, and regarded love itself as due to Grace:

> Love is not to be learned from men;
> it is one of God's gifts and comes of His grace.[6]

II. TIME IN MEDIEVAL EUROPE

One could amplify the above summary negatively, as follows, by contrasting it with ideas of time outside this region. During this time period, but in Europe, some ideas of quasi-cyclic time may have continued in the daily life of the peasant, but it was literally anathematized from theological and philosophical thought. This confused attitudes to quasi-cyclicity, a confusion which persisted throughout the period, and continues to this day.[7] While banishing quasi-cyclic time and replacing it by apocalyptic time, with heaven and hell lasting for eternity, Augustine imbued God with a number of powers. The better to justify the coercion of the State, Augustine quoted scriptures against the Donatist Christians to approve conversion by force.[8] (Al-Beruni in his *Kitāb al-Hind* noted the discrepancy between the Christian ethic of turning the other cheek, in principle, and the practice 'ever since Constantine the Victorious became a Christian' to 'ever' employ 'both sword and whip'.)[9] To complete this construction of God in the image of the State, the idea of love and compassion was replaced by the idea of justice: Augustine's God therefore would never forgive, but would extract eternal vengeance. In particular, the belief was that the world was created only a finite time in the past, but would last, in some form, for an eternity in the future.

Therefore, Augustine's idea was to (subjectively) construct time in such a way as to be able to blame people. (Augustine was a judge of imperial Rome.) To be legitimate, divine justice had to be rational; people had to be reasonably blamed. The key question which philosophers like Stephen Hawking still ask is this: 'It can hardly be one's fault if one has been pre-ordained to rob a bank. So why should one be *punished* for it?'[10] (Emphasis mine). Having made God so separate from man, powerful, and so remote, European philosophy during this period could not really admit the idea of Grace: like a clerical judge, God worked through fixed and immutable Laws—else how could his justice be rationally understood?—and only the Dunces (quite literally) thought otherwise.

European philosophy did however admit the closely allied idea of Providence. This Providence was not quite Grace, for it involved God's plan for the world (e.g. Adam Smith's 'hidden hand of God which had so nicely arranged things' that people were justly poor). The distinction between Providence and Grace is quite subtle, and generalizations are dangerous: though there was undoubtedly a belief in the miraculous power of prayer, western theologians avoided the implications of indeterminacy and emphasized the divine plan. The devout heretic Newton, unable to establish the stability of the solar system, retained some ideas of Providence; this Providence supplemented the Law-like causal unfoldment through which God usually worked. Newton's belief in the progressive understanding of prophecy was a retrospective affirmation of necessity.

The debate between rationality and Providence in Islamic theology was inherited by Christian theology. But, in Christian theology, God, built in the image of the State, had already been made so powerful that investing ever-greater powers in him was self-defeating: Man had to have some power, at least to wriggle, else he could not be justly blamed. Hence, ontically broken time, the basis of this Providence, was continually attacked from Thomas Aquinas to the collapse of the wavefunction in quantum mechanics, and to singularities. Hence, Stephen Hawking's latest approach to singularities emphasizes that 'One wouldn't have to say that God chose to set the world going in some arbitrary way that we couldn't understand... He [God] is not arbitrary.'[11] Henry Moore's ideas of Apocalypse, and apocalyptic time, flowing directly from the curse on 'cyclic' time, not only made Newton ecstatic[12] but deeply influenced his physics. Towards the end of this period, in Europe, Providence was abandoned by Laplace, who thought chance could only be epistemic (i.e., that probabilities could only represent ignorance, and not objective propensity, for example), a debate which is still on in quantum mechanics, and theology. Hence, the same old Augustinian idea of reconciling the determinism of God/Nature's laws with human freedom, through ignorance and talk of 'fatalism',[13] is being pursued today using theories of epistemically broken time which invoke chaos to make the deterministic laws of physics compatible with chance.

To simplify things, during this period, in Europe, in contrast to quasi-cyclic time and Grace, there was a belief in (1) apocalyptic time, with resurrection in heaven and hell for an eternity after a Day of Judgment; (2) hence a belief that the world was governed by God using immutable rational laws that could be progressively understood by Man, that God was not arbitrary (else how could Man be eternally blamed?); (3) that Providential interventions, such as lightning striking church spires, or interventions needed to keep the solar system going, were part of God's overall rational plan for the universe, to reward the good, and punish the bad people (both of whom He presumably created, according to plan).

III. THE COMPOSITE CULTURE

One cannot so simply amplify my summary of a physical world-view positively. One cannot so easily say that this or that group of people in India during that period subscribed to this or that picture of time. The reason is the absence of a simplistic theological homogeneity imposed by injunction and inquisition, and the prevalence instead of a composite culture. The period under consideration corresponds to the rise and fall of Muslim political power in India, from the earliest invasions of Mahmūd of Ghorī and Mahmūd of Ghaznī to the decline of Mughal power. The word 'Muslim' is only indicative of a wide spectrum of beliefs. At the level of the ruling elite, there was pressure because the requirements of orthodoxy were usually orthogonal to the requirements of political power. Thus, to gain Safavid support, Babur and Humayun declared themselves Shī'a. The full flowering of the Mughal empire took place under Akbar, who, from all accounts, was also personally attuned to this composite culture, and invited also the Jesuit missionaries. (These latter, while accepting his hospitality, seem to have told him nothing at all about their own system of branding those who did not agree with them as heretics, and subjecting them to an inquisition.) Ultimately, orthodoxy became uncomfortable with the width of the label 'Muslim', and tried to assert itself to the detriment of the Mughal empire which declined with Aurangazeb who declared himself a Sunni.

At the ground level, Islam, in the literal sense of surrender to the will of Allah, was comprehended not so much through the teachings of the *Ulema* linked to political authority, as through the teachings of the Sufis,[14] especially those delinked from political authority. The teachings of both Sufis and Ulema retained strong linkages to the happenings in Arabia and Persia, where Islamic theology did not stabilize until al-Ghazālī.

Al-Ghazālī

Both Sufis and orthodoxy claimed the legacy of al-Ghazālī.[15] Al-Ghazālī had rejected the Mu'tazilite philosophy of rationality (*aql-i-kalām*),[16] and the philosophers (mainly al-Fārābī and Ibn Sīnā, both of whom expounded Aristotle[17] in Islam). The Mu'tazilah believed in the two premises of (1) divine unity and (2) divine justice. (The first premise set the Mu'tazilah off from western Christian theology.) They thought that everything else followed by reasoning from these premises. The Mu'tazilah method of disputation confounded the heretics, making the Mu'tazilah very popular, and even institutionalized. Al-Ghazālī rejected the Mu'tazilah because he thought that philosophy subordinated the powers of God to those of reason. Reason had to start from premises that were not certain in themselves, but rested on the authority of the scripture or the consensus of the community. It did not provide the indubitable certainty that al-Ghazālī sought.

Against the Mu'tazilah, the Ash'arite school[18] had argued that everything consists of atoms and accidents: an accident cannot endure for two successive moments, and requires continuous creation by God of the atoms in which the accidents in here. One could not hope to rationally understand a world which evolved in such an ontically broken way. (Modern philosophers will recognize this as the unanswerability of Hume's objection to causality.) Hence, reason could not hope to grasp reality. The ways of God are inscrutable. Al-Ash'arl's attempt was to refute both the extreme determinists (al-Jabariyah) and the Mu'tazilah. He regarded voluntary actions as those which are created by God but 'acquired' by the human agent. In contrast, there is no human responsibility for involuntary actions, such as trembling.[19] This doctrine of acquisition (*kasb, iktisāb*) was a bit obscure,[20] and the Ash'arites insisted that like the Ku'rān this must be accepted 'without specifying how', inviting charges even from the Sunni's that it was a doctrine of compulsion (*jabr*).

In his *Tahāfut al-Falāsifa*[21] ('Destruction of the Philosophers') Ghazālī maintains that agency requires choice, so that inanimate or 'natural' causes cannot be agents or, properly speaking, causes, except in a metaphorical sense. (Hence, Ghazālī's rejection of the philosopher's idea of the world as necessary, or eternal, since this refutes the agency of God.)

> Fire which is an inanimate thing has no action. How can one prove that it is an agent? The only argument is from the observation of the fact of burning at the time of contact with fire. But observation only shows that one is *with* the other, not that it is *by* it and has no other cause than it.[22]

Al-Ghazālī goes on to illustrate this distinction between cause and correlation. If a blind man suddenly begins to see, he attributes this to the opening of the eyes. But when the Sun sets he realizes that 'the Sun was the cause of the impression of colours upon his sight'.

Al-Ghazālī now distinguishes causal necessity from logical necessity; he concedes only the latter as necessary. We assert a causal connection when we observe the constant conjunction of two events, such as eating and satiety or fire and burning, or decapitation and dying. However, it is *logically* possible for these conjunctions to be violated: the causally necessary is not logically necessary, hence causal necessity is no necessity. Hence, it is possible for God to create 'effect' without 'cause' or cause without effect, though this ontic breaking of the connection between cause and effect may appear miraculous, like the miracle reported in the Ku'rān of (Christ) resurrecting the dead. It is logically possible for cotton to be in contact with fire without burning, or for it to burn without contact with fire, and God might create such a sequence of events, if he so wished, though he usually creates things in a *habitual* sequence.

Al-Ghazālī presented the opposing point of view in a striking way that was more than fair. The opponent argues that one might have to say,[23]

> 'I do not know what there is now in the house. All I know is that I left a book there. Perhaps it has turned into a horse, defiling my library with its excrement. . .' one who sees a man whom he had not seen until now . . . might say, 'Maybe, this man was one of the fruits sold in the market. But now the fruit has been transformed into a man...'

This provided much fuel to his scholastic and other detractors, whose arguments were presumably too weak to withstand a fair presentation of *their* opponent's point of view. (The Thomist objections misrepresented Ghazālī, who, in his third discussion, permits causal efficacy to voluntary agents; the Thomist objection was that by reserving all causal power to God, Ghazālī had deprived man of the slightest creative power, so that a man could do the most horrendous things and pass on the blame to God.[24]) In the *Tahāfut,* al-Ghazālī does not advance any explicit system of his own:

> Ours was not the point of view of a system-builder. On the contrary, we only intended to throw their theories into confusion. And that purpose has been achieved.[25]

Though not necessarily its cause, al-Ghazālī's *Ihya' 'Ulūm-al-Din* ('Revival of the Religious Sciences') marked the beginning of the general downgrading of 'rational speculation' and knowledge (*logoi*), to elevate religious and ethical practice (*ergoi,* the way: *tariquā).*

However, the downgrading of reason was only partial and not wholesale as certain western Christian philosophers have maintained. Thus, Ibn al-'Arabī, the Sheikh of Sufis, wrote:[26]

> The meaning of philosopher is lover of wisdom, since *sophia* in Greek is 'wisdom', and *phil* is 'love', so the word means 'the love of wisdom' and every man of intelligence loves wisdom. However, the mistakes of the people of reflection in the divine matters (*ilāhiyāt*) are greater than their hitting the mark. . . they are criticized for the mistakes they made in the knowledge of God. . . If, while loving wisdom, they had sought it from God, not through reflection, they would have hit the mark in everything. . . for instance, they hold that if they were to apply to God the literal meanings of some of the words of the law-giver (*shāri'*), which the proofs of reason (*'aql*) hold to be impossible, they would fall into unbelief (*kufr*). Hence they interpret these words. They do not know that God has a faculty in some of His servants that gives a judgement different to the one given by the rational faculty in certain affairs, while it agrees with reason in others. This is a station outside the domain of reason, so reason cannot perceive it on its own, neither can reason (man) have faith in it, unless the person possesses that faculty within him. Then he knows that reason is limited and that (the existence of such a faculty) is true.

Orthodoxy

Therefore, despite al-Ghazālī's attacks on philosophers, the tendency to philosophize did not entirely disappear, and can be found even in the orthodox Sunnis of that time. For example, Abd ul-Haqq al-Dihlawī al-Bukhārī (1551-1642), of Delhi, opined:

> He is not in a place and not in a moment because all these are attributes of the world, and the Nourisher of the World is not subject to worldly attributes . . . His purposes are not subject to time. Time does not include or circumscribe Him. His existence is not dependent upon time. For in that condition when there was not time, there was He. Now also there is time and He exists. Therefore, He is not in time.[27]

Such philosophizing immediately threw up the contradictions between faith and reason:

> The Jabarites are those who say that fundamentally man has no choice and his motions are like those of inanimate nature. The Qadariya are those who say that man has choice . . . His actions are his own creations. Imām Ja'far says that both these two schools of thought are false and go to extremes. The true school of thought is to be found between them but reason is at a loss and confounded in the comprehension of this middle way. . .[28]

But the contradictions were now resolved by the belief in the inexplicability of the world, and by deriding as deviants those people who sought to understand.

> In truth this confusion is found among people of a disputatious and contending sort who wish to found articles of faith upon reason, and who will not acknowledge anything as true and believe in it unless it pleases their reason and falls within their understanding . . . The problem of divine power and ordination and the problem of man's choice become known to us by the traditions of the right path (*Sharī'a*). Since both are known from the Sharī'a, what is the controversy and the dispute about? One must believe in both. In this matter faith in the middle way is necessary. In truth, deep thought into this problem is among the indications of idleness and ignorance because no action and no truth is affected by controversy about it. One has to act. The real truth of the matter is that which is with God.[29]

A similar belief was prevalent in Europe till a little while later; in Locke's words, 'The omnipotent creator advised not with us in the making of the world, and His ways are not the less excellent because they are past our finding out.'[30]

The Sufis

While orthodoxy, at one end of the spectrum of beliefs, recognized only occasionalism (ontically broken time), the Sufis not only straddled the Shī'a-Sunni divide, they also incorporated the ideas of quasi-cyclicity and non-duality (*tauhīd*) in a way closely parallel to that of Advaita. They also claimed the authority of the Ku'rān—we breathed unto him (Adam) out of our own Rūh (*Nafākhtu fih min rubbi*)—for divine unity. One could possibly trace early Advaita influence on Sufis, either through Sind as Zaehner[31] does, or through the Arab seafarers who traded on the western coast[32] long before the invasion of Mahmūd of Ghorī, and one could similarly read Zoroastrian influence into Rūmī. But Sufi philosophy, as I understand it, was essentially inclusive, and it unambiguously emphasized the divinity, hence oneness of humanity, by breaking down the artificial cultural barriers between man and man.

Did Sufis like Rūmī really subscribe to transmigration? This point seems perplexing,[33] and has been debated by a number of scholars.[34] As one example, Khosla[35] quotes Rūmī's *Dīwān-i Shams-i Tabrīz*—'Man is born only once, I have been born many times'—to argue that the repeated births are 'spiritual, not physical', that Rūmī believed not in *reincarnation* (repeated lives in recurrent cycles of the cosmos) but in *resurrection* (life after death just once). In his eagerness to establish Rūmī's theological correctness and regard for tradition (as currently seen by the orthodox), Rūmī's creative synthesis seems to have eluded Khosla. Rūmī was not a heretic, but a mystic: he did not revolt, he evolved a creative synthesis; and he clearly saw *transmigration* as the appropriate creative synthesis between reincarnation and resurrection. (One should avoid confusing transmigration with metempsychosis, for it is the body, *jism,* that changes and not the soul, *psyche, rūh.*) There was no eternal recurrence, but there was spiritual progress; time was not supercyclic, but only helically quasi-cyclic: there was no permanency except at the end of the journey. Rūmī is clearly saying that he was born *as man* only once, but by virtue of his mystic insight, he could perceive his previous births, and his spiritual continuity with minerals, etc. The reference to minerals, etc. is not fortuitous, and clearly relates to Ibn al 'Arabī (*Fusūs al-Hikam,* 82) where one finds the same idea of a graded consciousness in all creation. Ibn al 'Arabī was a contemporary of Ibn Rushd (Averroes) who wrote the *Tahāfut al Tahāfut* ('Destruction of the Destruction')[36] against al-Ghazālī. In fact, al-Ghazālī is so identified with orthodoxy today, that it may come as a shock to learn that his only rebuke to al Hallāj for the assertion *'Ana'l Haqq'* ('I am the Truth'), for which Hallāj was 'whipped, mutilated, crucified (for three days), decapitated, cremated, and his remains scattered to the four winds',[37] was to chide him for divulging the secret which he ought not to have done.[38]

In fact, this idea is already quite explicit in Ibn Sīnā (Avicenna),[39] who thought of the soul as 'the principle of self-direction and growth in a body'.[40] Hence, everything inanimate and animate has a soul; inanimate matter also has a measure of creativity 'akin to that of the First Cause, for it is an emanation of that cause'.[41] In Ibn Sīnā's theory of evolution, the soul evolves from vegetable soul to animal soul to human soul, which alone can be described as a rational soul. (I may add here that, within current physics, it is possible to defend the idea of a universal substratum of low-level creativity, which is amplified in the living organisms that evolved later, provided, however, that one gives up the idea of a temporally antecedent First Cause.) Al Rāzī (Rhazes), the tenth century medical authority clearly asserted that the soul was addicted to the material world, and could be released from the 'wheel of birth' only through the therapeutic effects of philosophy.[42]

There are those like Ibn al-Fārid who rejected this theory. 'Have nothing to do with one that believes in *naskh* (the transmigration of soul into human bodies)—for his is a case of *maskh* (the transmigration of souls into the bodies of animals) . . . And let him alone with his assertion of *faskh* (the transmigration of souls into plants)—for if *raskh* (the transmigration of souls into minerals) were true, he deserves to suffer it everlastingly *in every cycle.*'[43] The emphasis suggests that the rejection of the theory was only partial.

As evident from the very need to evolve a creative synthesis, there is tension between the mystic teaching and resurrection. Resurrection is too narrow a doctrine—one quite deliberately invented by priests like Augustine to frighten people into submission—to accommodate the mystic teaching of the wandering of the *rūh,* (*rūh jāri,* not *rūh mūqīm*) corresponding to the Greek Mystery stories of the long night of the soul. My knowledge is admittedly limited, but I am not aware of even a single Sufi who, like Augustine, talked of salamanders, to explain why the doctrine of resurrection in the flesh was compatible with the flesh burning eternally in the fires of hell. In fact, this doctrine of an eternal distinction between man and God is specific to western Christianity, and Rūmī advocates exactly the pagan apocatastasis cursed by the western Church that all would become one.[44] That all are one with God was the basis of the Sufi doctrine of *tauhīd,* or of *wahdat al-wudjud* (the monism of being).

While al-Ghazālī, al-'Arabī, and Rūmī were all acknowledged as great teachers by the Sufis, the Sufi ideas started earlier, and included more. The idea of a Day of Judgement, associated with resurrection and apocalyptic time, was transformed back to its earlier form, under Sufi interpretation. This is how Abū Yazīd al-Bistāmī (d. 875), whose *shathāt* ('extravagances') al-Beruni quotes in his *Kitāb al-Hind,* described the encounter with God. In most Ku'rānic passages the throne of God is described as *'arsh,* but in two passages (K. II:255, and XXXVIII 3:4) as *kursyī.*[45] When Abu Yazīd reached the Divine Throne, it is said, he found it empty. So he sat down on it. His sitting on the throne is an allegory for his discovery of the divine element in himself. This idea of non-dualism is close to that of Advaita-Vedānta. In fact, al-Beruni had repeatedly noted the similarity in Indian, Greek, and Sufi traditions. Referring to Sāṁkhya-Yoga (*Bhagavad Gītā* and Patañjali's *Yoga-Sūtra*), he says:[46]

> The Sufi, too, do not consider the stay in paradise a special gain for another reason, because there the soul delights in other things but the Truth (*al haqq*), i.e. God, and its thoughts are diverted from the Absolute Good by things which are not the Absolute Good.

It is contrary to Sufi thought to stress the underlying physical world-view, and this has provided room to some scholars to question the precise nature of the underlying world-view, and to reinterpret it.[47] However, it must be remembered that Muslim orthodoxy became politically dominant only after the fall of Baghdad, and that in Mughal India it did not become dominant until the very end of the period under consideration. The *A'in-i-Akbarī* classifies the followers of Abū Yazīd (Bāyazīd) as orthodox,[48] while it classifies the Hulūli's and Hallāji's as 'the subject of much reviling'.[49]

Whatever scholars today may say about Sufis, the belief in the similarity of Indian and Sufi traditions continued right until the end of this period. (It still continues.) Akbar's grandson, Dara Shikoh, himself a Sufi of the Qādari order, in AH 1050 (AD 1657) translated the Upanishads ('the fifth Veda') into Persian, as *Sirr-i-Akbar* ('The Great Secret'): 'For . . . there are few thoroughly conversant with it even among the Indians. Thereby he also wanted to solve the mystery which underlies their efforts to conceal it from the Muslims.'[50] In the subsequent battle of succession, Aurangazeb not only slew Dara Shikoh, he tried to expunge this kind of 'heresy' to restore orthodoxy. Though he killed Dara, he could not expunge Dara's heresy of calling the Upanishads 'this abstract of Divine Unity (*tauhīd*),'[51] or his belief in cycles of time for which he quotes Hafiz:[52]

> There is no end to my story, or that of the beloved,
> For what hath no beginning can have no end.

Dara's heresy spread, for it was his translation of the Upanishads which first found its way into Europe, and was translated into French and Latin, and it was this re-translation which Schopenhauer found, a finding which further influenced Nietzsche, and, through him, Heidegger. As Heidegger emphasizes, the idea of time, particularly 'the doctrine of the eternal return of the same is the fundamental doctrine of Nietzsche's philosophy';[53] it is 'the very centre of Nietzsche's . . . thinking.'[54] However, in the process of making this combination of science and orientalia a potent political weapon, Nietzsche fell into the Augustinian trap of identifying quasi-recurrence with eternal recurrence, and reversed the ethical precepts followed by Dara—exactly like the Nazi's reversed the Indian swastika, a symbol of cosmic recurrence. Ultimately, only an original physicist like Envin Schrödinger, also influenced by Schopenhauer, could manage to see through the confusion to the core of Dara's Qādari position which coincided with the *Tat tvam asi* of the Chandogya: man has the freedom to create just because man is one with the Creator.

> In Christian terminology to say: 'Hence I am God Almighty' sounds both blasphemous and lunatic. But please disregard these connotations for the moment and consider whether the above inference is not the closest a biologist can get to proving God and immortality at one stroke.[55]

Bhakti

One cannot, of course, overlook the Dvaita Vedānta and Bhakti tradition. But I am not aware that they involved any ideas of time fundamentally different from those of quasi-cyclicity and ontically broken time (Grace) already considered. Moreover, I am not sure I understand the usual classifications, for it seems to me that, at the ground level, there were definite points of confluence where the Sufi and Bhakti streams merged. Mīrā's idea of a personified God as her lover, like the idea of God as oneself, are ideas foreign to the western Christian tradition, but these ideas were resonant with the belief in Grace. The Bhakti stream of thought, too, downgraded knowledge, and elevated religious and ethical practice as in Kabir's *ḍhāi ākhar prém ké* ('in this world, no one became learned by poring over manuscripts; there is more learning in two-and-a-half alphabets of love').

Ought one to classify Kabir? Born in a Muslim family, Kabir talked of Rāma, but his Rāma was not the Rāma of Tulsīdās, since 'Kabir's Rāma had no father': he was rather like the Nirguṇa Brahman. The *A'in-i-Akbari*, classifies[56] Kabir as a *Muwahhid:* one whose main concern is good action. The need to classify sharply can be problematic: the story is told that on Kabir's death, both Muslims and Hindus came to claim his body, the one to bury it, and the other to cremate it. The thorny issue was characteristically resolved by an act of Grace: when they went inside, they found only some flowers.

Interpreted as a moral injunction, Kabir's *doha* 'what you would do tomorrow, do today, what you would do today, do now. . .' has become a cliché along with its anonymous parody, 'what you would do today, do tomorrow, what you would do tomorrow, do the day-after; what is the hurry, Brother? You have to live for years.' What is the hurry? That sounds like the reaction of an agricultural society as uncomfortable with industrial punctuality and pace as the industrialized colonizer was with its lack of time-sense. Kabir's answer in the second line of the *doha*, taught to children, is not readily comprehensible for it synthesizes both ideas of quasi-recurrence and Grace, using the analogy of the cosmos as instant: the hurry is that the world will end in an instant.

IV. BUDDHISTS

The 'Cause' of the Buddhist Eclipse

In this atmosphere of religious integration, there was a terrible casualty rather early in the period: Buddhism—which did have a dissenting view of causality. This, to my mind, is one of the key puzzles of the period and region under consideration: how was Buddhism so completely eclipsed in India? Western historians will immediately interpret this question in terms of their own traditional doctrine of cause; I am here asking for the 'cause' in a sense most closely approximated by the Buddha's idea of *praticca samuppada*, or 'conditioned co-origination', which he used to forecast the fall of the Dhamma in five hundred years.[57] An attempt to carry out a 'causal' analysis along these lines may help to clarify the concept.

It is possible to refer to a multiplicity of causes:[58] internal corruption and decay, sectarianism, assimilation, withdrawal of State patronage. There is some truth to each of these, but the entire multiplicity is a little inadequate because, for example, Jains still survive. It could not have been merely the availability of State patronage elsewhere for Therāvāda had occupied south-east Asia, and the route to China through Mongolia had become dangerous for *Buddhists*. (After Śāntarakṣita and Kamalaśīla, though trade continued, there were no further Buddhist travellers from China, and no further Buddhist texts went from here.) It could not have been merely the invaders from the north-west who, led by Muhammad-i-Bakhtiyār Khaljī, sacked the university of Nālandā, in 1190 (and that of Vikramaśilā a little later), and butchered in large numbers the unarmed Buddhist monks, 'the Brahmanas with shaven heads', as recorded in the *Tabakāt-i-Nāsirī*.

> The greater number of the inhabitants of that place were Brahmanas, and the whole of these Brahmanas had their heads shaven; and they were all slain. There were a great number of books there; and when all these books came under the observation of the Musalmānas, they summoned a number of Hindīs that they might give them information respecting the import of these books, but the whole of the Hindīs had been killed . . . it was found that the whole of that fortress and city was a college, and in the Hindūs tongue, they called a college . . . Bihār.[59]

But the Buddhists could have fled south instead of to Tibet; and if they didn't flee south it must have been that they did not feel safe there, or did not find sanctuary there. The eclipse of Buddhism could not have been merely due to Brahmanical persecution, Tāntrism and the rise of Vajrayān, for while it is very probably true that some Śaivite kings did persecute Buddhists in Bengal, in some cases even putting a price on their heads, it is also true that Islam won the most converts in precisely those regions (*viz.* Bihar and Bengal) which were earlier under the most Buddhist influence. As suggested by the association of Buddhism with Tantra, hence Lokāyata (rejected by the Buddha), the Buddhists presumably came from the poorer strata of society and from lower castes.[60] It is also true that most of the subsequent Islamic converts were poor and from the lower castes—this is still true today. (In contrast, the Jains, though better assimilated, were rich, for their philosophy of non-violence prohibited Jain householders from taking up any profession other than that of moneylending or trade—this is still true today.)

Though this is a fascinating line of enquiry in itself, I would here like to focus on the following sub-question. The south was blocked with the rise of Advaita Vedānta, and the hostility is clearly recorded in the *Keralottpatti*, and the very title of Madhva's *Śaṅkaradigvijaya*. How should one account for this hostility considering the barely perceptible differences between Nāgārjuna's *śūnyavāda*, and Śaṅkara's *māyāvāda*? The insignificance of the difference is not due only to our temporal distance. The seventh chapter of Kamalaśīla's commentary on Śāntarakṣita's *Tatvasamgraha* is called *ātmaparīkṣā*, and 'tests' the doctrine of the soul as 'imagined' by the Upanishads. He explains the rejection of the Vedānta doctrine by 'a slight fault (*alpa aparādha*) in their theory', (though the theory rejected does not coincide with Śaṅkara's). A Jaina writer of the same period, Akalanka, criticizes the theory of Advaita for the same faults as the Buddhist theory. Śaṅkara was accused of importing Buddhist ideas. Thus, the difference is intrinsically confusing, and I elaborate this below.

Quasi-cyclic Time in Advaita Vedānta

The idea of time in the Upanishads, hence in Advaita, is clearly quasi-cyclic, as I have explained in an earlier article[61] in this series. Some apologists like Arvind Sharma have erroneously denied this,[62] perhaps with the hope that such a denial would make the Upanishads more 'relevant' to our times, or more appealing in the modern western context. I think such a point of view is not worth refuting in detail

Quasi-cyclic Time and Conditioned Co-origination

What is more perplexing is the role of quasi-cyclicity in Buddhist thought. This may be clarified as follows. The Buddha believed, but did not believe in life after death in the following sense. He granted the belief in quasi-cyclic time, but *not* in the soul as an *unchanging* substratum which connected two bodies. He granted that memory continued across lives, but *not* that memory constituted identity (or the other way around), because something changed across cycles of the cosmos, but also across two instants. (Instants are to be visualized exactly like cycles of the cosmos, using the analogy of the instant-as-cosmos which inverts the more traditional analogy of cosmos-as-instant. In particular, the atomic instant is to be thought of as having some 'structure', so that logic is not necessarily two-valued or even truth-functional.) How should one say that some constant thing (the *ātman*) connected bodies across two cycles of the cosmos, or across two instants of time? The proof or disproof of the existence of the *ātman* was to be found not by killing a man in a pot, or weighing him before and after death, as Pāyāsi did, but by its *causal efficacy*. Thus, a thing exists if it has causal efficacy (perceived, or inferred, not testified), for example, a past event does not cease to exist if it has not yet produced its effects. (In relativistic terms, it might happen that one interacts only in the future with an event which is now in the relative past.)

Given the Upanishadic idea of equating immortality with freedom from rebirth, in what sense did the *ātman* exist earlier, and in what sense did it cease to exist after deliverance? Since the *ātman* was immortal it could not cease to exist, it dissolved into the *Brahman*. Its causal efficacy ceased. But how could an eternal thing change? Hence, it must never have had any causal efficacy. Hence it did not ever exist. The enlightened man himself did not cease to exist (this was the 'effect' of past acts); but his present acts bore no more fruit in the future. Thus, it was only the actions that had causal efficacy. Only the acts could be said to exist.

But a cause must always produce its effect (assumption). So how could actions produce fruit in one case and not in another? The answer could be understood in analogy with the idea of a multiplicity of causes. A seed did not produce a plant. It was the seed together with the earth and water. The seed in the granary was incapable of producing a plant, it could only produce (a near replica of) itself, which it did every instant. The seed in the ground was capable of producing a plant (it was a different seed, being bloated up etc.). In common parlance one overlooks the difference between the two seeds and calls them the same seed (since the language is inadequate to express notions of time not in it). Also, it is a mere convention that the seed is the 'main' cause, and earth and water are 'supporting causes'.

This directly led to the Buddhist way of life. Suffering conditionedly co-originates with actions; it is not 'due' to the actions (*karma*) alone, but also to attachment and a craving for the fruit. Cessation from suffering meant cessation from existence (not the same as death), which could be achieved only when the causal efficacy of acts ceased, and that could be obtained only through detached action.

To summarize, in Buddhism, quasi-cyclicity, though granted, is largely irrelevant, for it merely lengthens a string of instants. Death, too, is irrelevant, for it only means 'intermediate non-perception', and existence is decided by causal efficacy, not by perception. (Those who require models to understand everything, should think of, for example, the 'diluted presentation'[63] explanation of H.G. Wells' time machine which exists but is not perceived!) As regards the way of life, the difference that the belief in life after death makes to the Buddha's way is that it blocks suicide as a possible method of release from suffering, and offers householders the possibility of Nirvāṇa in future lives.

Conditioned Co-origination and Social Reorganization

There is undoubtedly a distracting similarity between the two sets of beliefs. Philosophically, a key point of divergence is in the rejection of *testimony* as a valid *pramāna*, and the retention of only the manifest (*pratyakṣa*), and the inferred. This means the rejection of the tradition—i.e., Vedas—as a source of valid knowledge. In practical terms this meant the rejection of the traditional organization of the society. Thus, the Buddha did not merely propound an abstract and subtle doctrine of causality as the fruit of his extended meditations. He applied it to start a new social organization in the *sangha*, which departed from tradition. One key feature of the *sangha* was its explicitly democratic character which, unlike the 'democracy' of Athens, admitted both 'slaves' and women as equals. Though the *sangha* has been regarded as organized along tribal lines,[64] the fact is that admission to a tribe is hereditary, whereas admission to the *saṅgha* was on the principle of majority vote (with the assent of those who kept quiet after three chances being presumed) .

It was at the level of social organization, implied by non-belief in the *ātman*, that the rise of Buddhism posed the greatest challenge to the traditional way of life. *The theory of conditioned co-origination explicitly denied that individuals were the sole causes.* Therefore, it also denied that they were the appropriate recipients of credit and blame. *It therefore denied that the social hierarchy reflected a distribution of merit.* For in Buddhism the cessation from suffering is available now. It is available at the very next instant. Buddhism emphasized the capability of creative action (*purusakāra*), more than hereditary dispositions (*samskāra*). Nirvāṇa was available to a poor person from the lowest caste, and he or she could join the *saṅgha*. It was not necessary for a person to wait to be reborn into a higher caste before seeking deliverance; deliverance was available now if the person were so motivated. The traditional social order was not necessarily a moral order.

Since even perceptive scholars like the two Kosambis seem to have overlooked the key role of the idea of 'cause' in the organization of society, I would like to present a closer example. One can better understand the relation of 'cause' to social organization by applying conditioned co-origination to our present situation of industrial capitalism. The objective here is not to obtain deliverance, but to maximize happiness or ordinal 'utility', which reduces to cardinal money on the equation *time = money:* live so as to maximize the (expected present-value of) lifetime income. A capitalist society is necessarily organized so that only a few people have capital. Those who don't have money (most people) must first spend their lives trying to earn money to be happy. Conditioned co-origination denies that this distribution of wealth reflects a distribution of 'merit', or is otherwise legitimate. It denies that poor means bad, as in 'poor argument'. It accepts that much suffering would cease if society were reorganized to remove these disparities. It denies that wealth can be legitimately inherited. A further elaboration of this idea would be out of place here. The point is only that the formation of the *saṅgha* as a separate entity represents, therefore, a moderate rather than a revolutionary presentation of this perception of social organization, through a changed notion of cause.

And, I believe, it was through social reorganization around temples rather than at the level of purely philosophical ideas that Advaita Vedānta refuted Buddhism. The *matha* system was influenced not so much by the Buddhist *saṅgha* as by the hierarchical religious organization of Syrian Christianity, and also its burial customs,[65] which seem to me to be of foreign origin, for they seem to me to flow from a different perception of life after death, which seeks the preservation of the body rather than its complete annihilation and dispersal after death. By Saṅkara's time there was a well established Indian diocese at Kotinallur, less than fifty kilometers from Kaladī, and the Syrian Christian tradition then was already half a millennium old. Their surviving written records, however, go back to a little after Śaṅkara.[66] It is not entirely a different matter that Christianity itself was influenced by the ideas of compassion (love), missionaries, congregational prayer etc., and even western Christianity once accepted St Jesophat Bodhisattva.

The tradition was revived around temples, presumably because they could accumulate the money to support this revival. But al-Beruni tells a slightly different story. Mahmūd of Ghaznī wanted to destroy the temples, and 'punish those who kept idols and would not acknowledge the unity of God.'[67] He destroyed the image at Somnāth and threw part of it 'before the door of the mosque of Ghaznin, on which people rub their feet to clean them from dirt and wet.'[68] Al-Beruni reported to him, in his *Kitāb al-Hind,* first that the society was stratified. That is, he stated, there was greater similarity between the Indian elite and the Greek elite than there was between the Indian elite and the common people in India, or between the Greek elite and the common Greek.[69] Now, he points out that 'this is what the educated people believe about God. They call him *īśvara,* i.e., self-sufficing...'[70] He contrasts these notions with the vulgar notions of God prevalent among illiterate and semi-literate people. He explains how the reference in the Ku'rān to the hands of God were similarly misunderstood due to tricks of the priests and theologians. He goes on to say:

> For those who march on the path of liberation, or those who study philosophy and theology, and who desire abstract truth which they call *sāra,* are entirely free from worshipping anything but God alone, and would never dream of worshipping an image manufactured to represent him.[71]

It seems reasonable to presume that al-Beruni's analysis had an impact on the rulers of Ghaznī, for it is true that the Sultān shared power with the stronger Hindu elements. A raid is one thing, and a stable rule is another. A stable rule would not, in any case, have been possible without sharing power with the elite. The *A'in-i-Akbarī* says exactly the same thing:[72] 'They one and all believe in the unity of God, and as to the reverence they pay to images of stone and wood and the like, which simpletons regard as idolatry, it is not so. The writer of these pages has exhaustively discussed the subject with many enlightened and upright men....'

What did al-Beruni say about Buddhists? The usually knowledgeable al-Beruni is at a loss here. He thinks of Buddhists as foreigners.

> Another circumstance which increased the already existing antagonism between Hindus and foreigners is . . . the so-called Shamaniyya (Buddhists), though they cordially hate the Brahmans, still are nearer akin to them than to others. In former times, Khurāsān, Persis, 'Irāk, Mosul, the country up to the frontier of Syria, was Buddhistic, but then Zarathustra went forth... The succeeding kings made their religion (i.e., Zoroastrianism) the obligatory state-religion for Persis and 'Irāk. In consequence, the Buddhists were banished from these countries, and had to emigrate to the countries east of Balk... From that time dates their aversion towards the countries of Khurāsān.[73]

He speaks of 'Buddhodana' who calls his adherents '*buddha, dharma, saṅgha,* as it were *intelligence* (buddhi !), *religion,* and *ignorance*'.[74] The reason for this profound ignorance emerges later on:[75]

> I have never found a Buddhistic book, and never knew a Buddhist from whom I might have learned their theories . . . all I relate of them I can only relate on the authority of Al érānshahrī, though, according to my mind, his report has no claim of scientific exactness, nor is it the report of a man who has a scientific knowledge of the subject.

I cannot say to what extent the Muslim rulers of Delhi ultimately learnt about the Buddhists.[76] But I do know what Buddhists had to say about the notion of God and creation. (Al-Ghazālī classifies as unbelievers, rather than heretics, those who do not believe in creation.) Using his famous *prasaṅga* (*reductio ad absurdum*), Nāgārjuna showed that the idea of an omniscient, omnipotent, and good God is incompatible with the existence of suffering in the world. In Śāntarakṣita's *Tattvasaṁgraha*, with the commentary of Kamalaśīla's there is a comprehensive denial of God as creator of the world.

> Entire negation of Him (*Puruṣa*) also, as in the case of *Īśvara* should be stated. For why would this (*Puruṣa*) perform activity of this kind (i.e., creation of the world, etc.)? If because of being prompted by another, then *Puruṣa* would not have independence. If out of compassion, then He would make a purely pleasant world... If He acts from sport, then He would not be the master of that sport, for like a child, He needs accessories with which to sport... If ... due to his own nature, just as ... burning . . . belongs to fire . . . due to nature alone . . . everything would be originated from Him at the same time, because the cause with the power to originate them would be existing.[77]

This is followed by a refutation of 'Sauri (Viṣṇu), Ātmaja (Brahmā) and the like' as possible creators. Kamalaśīla explains that 'and the like' refers to Time, which is conceived by some opponents to possess wisdom as is explained by their claim:

> Time ripens the beings.
> Time annihilates the creatures.
> Time awakes when (people) are deep asleep.
> Time is indeed invincible.[78]

The Buddhist arguments were strong, but they defended the politically weak. The revival of tradition around temples must also have revived tensions within the two strata of society. How would the elite have managed the tensions? How did this stratification affect the political strength of the society? When the knowledgeable al-Beruni learnt so many things about India, did he not eventually learn that the Buddhists were atheists who openly denied both the existence of God and the creation of the world? Why would the elite want to hide this information from him? Were the later invaders too unaware of Buddhist atheism? These are questions which I leave to other historians to answer.

Intention and Indirect Causation

There is only one final point which I want to clarify about the role of intention. The Jain non-acceptance of intention led to so extreme a doctrine of non-violence, that it made it difficult to live. To live, even the Tīrthāṅkaras had to eat, and cooking the food entailed the possibility that some insect might unwittingly die in the process. Thus, the Jains replaced (non-)intention with the doctrine of indirect causation, as the means of legitimation. The second Bhadrabāhū (roughly a contemporary of Diṅnāga), in his ten-limbed syllogism,[79] expounds how a Tīrthāṅkara may eat food cooked by a householder, *provided the food was not specially cooked for him.* As a corollary, one can easily justify the indirect violence of the State on which Jain householders necessarily relied, for they could only be traders and moneylenders by profession.

To summarize, the Buddhist idea of spreading the teaching flourished for fifteen hundred years. It travelled abroad and was transformed, for example to Zen. Elsewhere it was converted to a doctrine of conversion by force, whether direct or indirect. This doctrine of establishing truth by religious authority and sword returned in a pincer movement via south and north to cut off Buddhists in the land where Buddhism was born, for force played a compelling role in refuting the Buddhist arguments.

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1. The idea of a spherical earth is commonly found in the scholarly literature of the period. (Throughout the period an important instrument was the astrolabe, which embodied a planispheric projection of the cosmic globe.) The idea of a spherical earth was already incorporated in the Siddhāntic literature translated into Arabic before the commencement of the epoch under consideration. Al-Beruni himself translated the late fifth and early sixth century *Pañcasiddhāntikā* of Varāhamihira, which proceeds on this idea. G. Thibaut and Sudhakara Dwivedi (tr.) *Pañcasiddhāntikā,* reprint, Chowkhamba Sanskrit Series, Varanasi, 1968, 13.27 and 13.9-13, pp. 70, 72.
2. Sachau conjectured that he was a political prisoner, partly on the grounds that al-Beruni does not adequately glorify Mahmūd (as he does his drunkard son, Mas'ūd), but says of him that 'He utterly ruined the prosperity of the country (of India) . . .' E.C. Sachau, *Alberuni's India,* Keagan Paul, Trench, Trubner & Co., London, 1910, reprinted, Munshiram Manoharlal, New Delhi, 1983, 2 vols., preface.
3. Al-Beruni's method was, first, to measure the height of a hill by measuring the angles subtended by the hill at two points a known distance apart, and applying the usual trigonometric formula. He then climbed the hill and measured the angle of dip of the horizon. Assuming the Earth to be a perfect sphere, the line of sight is tangential to the sphere, hence orthogonal to the radius, and a simple calculation gives the radius, hence the circumference of the Earth. Al-Beruni's value of the radius of the Earth was equal to 3938.77 English miles (using 1 Arabic mile = 1.225947 English miles). This compares favourably with the mean radius of curvature of the reference ellipsoid, at his latitude, which is 3947.80 miles. Al-Beruni's self-constructed instrument could accurately measure angles to at most a minute of the arc, so the key to the accuracy is the high-precision finite-difference interpolation technique used to construct sine tables. Al-Beruni translated the *Karana Tilak* of one Vijaya Nandi of Benares, for Zij calculations, as *Ghurrat-uz-Zijāt,* the manuscript of which was discovered in 1959. The *Karana Tilak* falls in between the *Karana Khandakhadya* of the sixth century Brahmagupta (who explicitly uses the idea that the first sine differences are proportional to cosines, and whose work al-Beruni had thoroughly studied) and the *Karana Kutuhula* of the second Bhāskara. See S.S.H. Rizvi, 'A Newly Discovered Book of al-Beruni: "Ghurrat-uz-Zijāt" and al-Beruni's Measurements of Earth's Dimensions.' In, H.M Said (ed.) *Al-Beruni Commemorative Volume,* Hamdard Academy, Karachi, 1979, pp. 605-80.
4. For some more details on how ideas of time are intertwined with religious philosophy, see R. Sorabji, *Time, Creation and the Continuum,* Duckworth, London, 1982.
5. R.A. Nicholson (tr.), *Translation of Eastern Prose and Poetry,* Curzon Press, London, 1987, p. 155. See also Henry Corbin, *Cyclical Time and Ismaili Gnosis,* Keagan Paul, London, 1983.
6. R.A. Nicholson, *A Literary History of the Arabs,* T. Fisher, Unwin, London, 1907, p. 385.
7. E.g. Stephen Hawking trying to make plausible his 'chronology protection conjecture' against time travel, uses singularities, originally derived by using the same idea as a postulate: the chronology condition! See, S.W. Hawking, 'Chronology Protection Conjecture', *Phys. Rev.,* D 46 (1992) 603-11; S.W. Hawking and G.F.R. Ellis, *The Large Scale Structure of Space-time,* Cambridge University Press, 1973. C.K. Raju, *Time: Towards a Consistent Theory,* ch. 7, Kluwer Academic, Dordrecht, 1994.
8. Augustine argued against the Donatists that to talk of the moral qualities of the priest performing the baptism was a heresy against which the use of state power guided by a Catholic emperor was justified. If this was persecution by the state then it was persecution as the workers practised it in the gospel when they were sent by their master to the highways with the order 'to coerce' the poor 'to come in' (Luke 14:23); it was the persecution of the shepherd who 'persecutes' the lost sheep, bringing it back to the flock, even against its will, and thus saves it (Matt. 18:12-14). 'Why should not the Church compel its lost sons to return, if the lost sons compel others to their ruin?' Augustine letters 93 and 185, Ep. 185, 6, 123. Further comments in A. Mandouze, *S. Augustine,* p. 348. Herbert Jedin and John Dolan (eds.) *History of the Church,* vol. II: *The Imperial Church from Constantine to the Early Middle Ages* (tr. Anselm Biggs), Burns and Oates, London, 1980.
9. E.C. Sachau, *op. cit.,* vol. 2, p. 161.

10. Stephen Hawking, *Black Holes and Baby Universes and other Essays*, Bantam Books, Toronto, 1993, p. 115.
11. *Ibid.*, p. 158.
12. Moore to Sharp, 16 August 1680; Marjorie Hope Nicholson (ed.) Conway letters, *The Correspondence of Anne, Viscountess Conway, Henry Moore, and Their Friends*, New Haven, 1930, pp. 478-9, in, Richard S. Westfall, *Never at Rest: A Biography of Isaac Newton*, Cambridge University Press, 1983, p. 349.
13. Augustine, *The City of God*, V.9, tr. Marcus Dods, in, R.M. Hutchins (ed.), *Augustine, Great Books of the Western World*, vol. XVIII, Encyclopaedia Britannica, Chicago, 1952, p. 215.
14. While the teachings of the Sufis varied, Allah was worshipped as *Al-Haqq* (the Truth), who could be attained only through ecstasy (*wajd*). Al-Nūrī defined Sufism (*Tasawwuf*) as 'hatred of the world, and the love of the Lord.' According to Junayd, '*Tasawwuf* is this: that God should make thee die from thyself, and should make thee live in Him.' R.A. Nicholson, *A Literary History of the Arabs*, T. Fisher Unwin, London, 1907, p. 392. In view of the conflicting etymologies, explicit since al-Beruni, I am tempted to define a Sufi as one who keeps his heart *ṣafi* (pure), has wisdom (Sophia), and wears a cloak of *ṣūf* (wool)!
15. Ghazālī means 'wool', so to spell it as al-Ghazālī implies that his father was a poor spinner, which he apparently was not. W. Montgomery Watt, *Islamic Philosophy and Theology*, Edinburgh University Press, 1962, Paperback, 1979.
16. H.A. Wolfson, *The Philosophy of the Kalām*, Cambridge, Mass., 1976.
17. The so-called theology of Aristotle actually consisted of quotations and paraphrases of parts of the *Enneads* of Plotinus. See, e.g. R.C. Taylor in Parviz Morewedge (ed.) *Neoplatonism and Islamic Thought*, SUNY, Albany, 1992.
18. This represented the first phase of Sunni consolidation, under the requirements of 'Abbasid jurisprudence, which required the authority of tradition, hence a standardization of tradition through a chain of authorities (*isnād*) leading back to a companion of the Prophet. In particular, orthodoxy felt a need to suppress the proliferation of tradition through reinterpretation.
19. Majid Fakhry, *Islamic Philosophy*, Columbia University Press, New York, 1970, p. 237. Also, Majid Fakhry, *Islamic Occasionalism*, London, 1958; ultimately, the Ash'arites decided the worth of an action by revelation and religious law. Majid Fakhry, *Ethical Theories in Islam*, E.J. Brill, Leiden, pp. 48-9.
20. W. Montgomery Watt, *op. cit.* p. 86.
21. S.A. Kamali (tr.), *Al-Ghazālī's Tahāfut al-Falāsifā*, Pakistan Philosophical Congress, Lahore, 1958.
22. *Ibid.*, p. 186. Emphases original.
23. S.A. Kamali (tr.), *op. cit.*, p. 189.
24. Majid Fakhry, *op. cit.*, p. 234.
25. S.A. Kamali (tr.), *op. cit.*, p. 87.
26. *Futuhat*, II, p. 523; cited by Mahmoud al-Ghorah, in, Stephen Hirtenstein and Michael Tiernan (eds.) *Muhyiddin Ibn 'Arabī*, Element, Shaftesbury, 1993, p. 208.
27. *Tahmīl ul-Imān*, in Wm. Theodore de Bary *et. al.*, *Sources of Indian Tradition*, reprint, Motilal Banarsidass, Delhi, 1972, pp. 396-7.
28. De Bary *et al.*, *op. cit.*, p. 399.
29. *Ibid.*, pp. 399-400.
30. *Works of John Locke*, 1768, I, p. 750; in Mary Hesse, *Forces and Fields*, Greenwood, Westport, 1970, p. 167.
31. R.C. Zaehner, *Mysticism: Sacred and Profane*, Clarendon, Oxford, 1957, and *Hindu and Muslim Mysticism*, London, 1960. Zaehner finds a number of parallels and argues, for example, that Abū Yazīd's teacher, Abū Alī al-Sindī, was familiar with the doctrine of Advaita, and that there are clear parallels between Yazīd's utterance, 'I am God, worship me', and 'That art thou' (*tat tvam asi*) of the *Chandogya*, or Yazīd's 'Glory be to me' and the *Sannyan* Upanishad's 'homage to me' (*mahyam eva namo*), or between 'Neti, Neti' and Dhu'l-Nūn al-Misrī's 'Whatever you imagine, God is the contrary of that', and so on.
32. R.A. Nicholson, *op. cit.*, suggests that there is some truth in each of the theories of Neoplatonic, Vedāntic, and Zoroastrian influence, and further that these theories are not exclusive: an immediate Neoplatonic influence does not rule out a much earlier Vedāntic influence. The point here, however, is not to decide which theory is true, but that the similarity of the doctrines made it so much easier to assimilate Sufis in the culture.
33. This point was not perplexing to al-Beruni. If today it seems perplexing, it is because of the theological battles with Sufism fought by the more orthodox like Sheikh Ahmad Sirhindi. He reversed the tactic that the Sufis applied to orthodoxy: since he could not repudiate Ibn al-'Arabī, he simply reinterpreted him, claiming in his *Maktibāt* (*Letters*) that Ibn al-'Arabī had confused the 'unity of existence' (*tauhīd-i-wujūdi*) with the 'unity of experience' (*tauhīd-i-shuhūdi*) (folio 52-53b, De Bary *et. al.*, p. 449). He was clearly inspired by concerns of the state, alluding to Akbar as a sick soul prohibiting Islam (folios 58b-59b, De Bary *et al.*, p. 454). His views were too extreme for Jehangir, though he was restored to favour shortly

before his death in 1624. On the other hand, S.H. Nasr, *Sufi Essays,* George Allen and Unwin, 1972, has adduced a number of theological arguments about the orthodoxy of Sufism.

34. Margaret Smith, 'Transmigration and the Sufis', *Muslim World,* 30 (1940), 351-7. W. Montgomery Watt, *Free Will and Predestination in Early Islam,* Luzac and Co., London, 1948. Jane I. Smith and Yvonne Y, Haddad, *The Islamic Understanding of Death and Resurrection,* SUNY, Albany, 1981; A.J. Arberry, *Reason and Revelation in Islam,* George Allen and Unwin, London, 1957, pp. 38-9. Majid Fakhry, *A History of Islamic Philosophy,* Columbia University Press, New York, 1970, pp. 119-20, 145-7. A.S. Tritton, *Muslim Theology,* 1947, pp. 136-9. E.G. Browne, *A Literary History of Persia,* Cambridge University Press, 1969.
35. K. Khosla, *The Sufism of Rūmī,* Element Books, Longmead, 1987, p. 237.
36. S. Van den Bergh (tr.), *Averroes' Tahāfut al-Tahāfut* (*The Incoherence of the Incoherence*), London, 1954.
37. Majid Fakhry, *op. cit.*, p. 275.
38. Al-Ghazālī, *Miskāt al Anwār,* p. 108, in M. Umaruddīn, *The Ethical Philosophy of Al-Ghazālī,* Aligarh Muslim University Press, 1962, p. 41.
39. Majid Fakhry, *op. cit.*, pp. 156-60.
40. Krishna Chaitanya, *A History of Arabic Literature,* Manohar, New Delhi, 1983, pp. 98-9.
41. *Ibid.*
42. Majid Fakhry, *op. cit.*, p. 120.
43. R.A. Nicholson, *Studies in Islamic Mysticism,* Cambridge University Press, 1921, p. 257, emphasis mine.
44. A.J. Arberry (tr.), *Discourses of Rūmī,* p. 40. 'So on the resurrection day, since the affairs of all will be with God, they will all be one in this real sense.'
45. 'Kursyī', *Shorter Encyclopaedia of Islam,* pp. 286-7. F. Rosenthal, 'The Empty Throne', *Studia Islamica* 31, 1970, pp. 237-8. B.E. Lawrence, 'Al-Beruni and Islamic Mysticism', p. 367, in H.M. Said (ed.) *Al-Beruni Commemorative Volume,* Hamdard Academy, Karachi, 1979, pp. 362-79.
46. E.C. Sachau, *op. cit.*, vol. I, pp. 62-3.
47. Bruce E. Lawrence, 'Al-Beruni and Islamic Mysticism', in *Al-Beruni Commemorative Volume, op. cit.*, pp. 369-79.
48. III, pp. 389-90.
49. *Ibid.*, p. 393.
50. De Bary *et. al.*, *op. cit.*, p. 448. Dara speaks of himself in the third person.
51. Text and translation in S.A.H. Abidi, *Sufism in India,* Wishwa Prakashan, New Delhi, 1992, p. 114.
52. *Ibid.*, p. 110.
53. Martin Heidegger, *Nietzsche,* (tr.) D.F. Krell, Harper Collins, San Francisco, 1991, vol. II, *The Eternal Recurrence of the Same,* p. 6.
54. *Ibid.*, vol. I, *The Will to Power as Art,* p. 23. As I have explained elsewhere, unlike Heidegger, Nietzsche's ideas of time were not metaphysical but based on *physics,* using a Markovian analogue of Poincaré's recurrence theorem, which frustrated Boltzmann's attempts to *prove* the entropy law. The statements and proofs of the theorems may be found in C.K. Raju, *op. cit.,* ch. 4.
55. Erwin Schrödinger, *What is Life?,* (1944), reprinted Cambridge University Press, 1992, 1995, p. 87.
56. *A'in-i-Akbarī,* II, p. 182. See also, S.A.A. Rizwi, *A History of Sufism in India,* vol. I, Munshiram Manoharlal, Delhi 1978, p. 373.
57. *Vinaya Piṭakā,* 2.256.
58. R.C. Mitra, *The Decline of Buddhism in India,* Vishwa Bharati, 1954, pp. 125-64. S. R. Goyal, *A History of Indian Buddhism,* Kusumanjali Prakashan, Meerut, ch. 20.
59. *Tabakāt-i-Nāsirī, A General History of the Muhammadan dynasties of Asia including Hindustan from AH 194 (AD 810) to AH 658 (AD 1260) and the Irruption of the Infidel Mughals into Islam.* Maulāna, Minhaj-ud-dīn, Abū-'Umar-i-'Usmān. Tr. from the Persian by H.G. Raverty, vol. I, reprint, Munshiram Manoharlal, New Delhi, 1970, vol. I, p. 552. The sequel recounts how Muhammad-i-Bakhtiyār carried his campaign into Tibet, but got trapped and lost almost all his men, returning with only a hundred or so men, and died heartbroken.
60. It is not clear that king Harshvardhan had indeed converted to Buddhism. See, e.g., S.R. Goyal, *op. cit.*
61. C.K. Raju, 'Time in Indian and Western Traditions and Time in Physics', In *Mathematics, Astronomy and Biology in Indian Tradition: Some Conceptual Preliminaries,* (eds.) D.P. Chattopadhyaya and Ravinder Kumar, PHISPC, New Delhi, 1995.
62. Arvind Sharma, 'Cyclic Time...' reproduced in *Time in Indian Philosophy,* compiled with an introduction by H.S. Prasada, New Delhi, 1994.
63. H.G. Wells, *The Time Machine,* 1895. Wells starts by pointing out that something which has only length, breadth and height does not exist (just as a point or a line or a plane do not exist), since it exists only for an infinitesimal amount of time. Contrary to what is stated in Nahin p. 274, note 1 to chapter 4, Wells does have one of his characters, the Psychologist, pass his hand through the place where the time machine had

been. P.J. Nahin, *Time Travel in Physics, Metaphysics, and Science Fiction*, American Institute of Physics, New York, 1993.

64. D.D. Kosambi, *An Introduction to the Study of Indian History*, Popular Prakashan, Bombay, 1956.
65. The Śaṅkarācāryas, like Syrian Christian Bishops and Archbishops, are to be *buried*, not cremated, in a sitting position. I had a recent sad occasion to observe this at first hand, on the death of my friend Paulos Mar Gregorios, Metropolitan of Delhi. A little crisis was created since his body had to be carried in a sitting position to Kottayam.
66. Stephen Neill, *A History of Christianity in India: the Beginning to 1707*, Cambridge University Press, London, 1984, p. 45. The record refers to *c.* 823 when the Catholics of the east governed the diocese of India and Malabar, and the Syrian Fathers Mar Sakor and Mar Parut came to Kullam and met king Shakirbirtthi (Vira Raghava Chakravarti).
67. As narrated by 'Utbi, a contemporary historian, quoted by H.M. Eliot, *The History of India as told by its Own Historians*, London, 1869, in *Ta'rikh-ul-Hind*, quoted by A.S. Khurshid, in *Al-Beruni Commemorative Volume, op. cit.*, p. 359.
68. E.C. Sachau, *Alberuni's India, op. cit.*, vol. II, p. 103.
69. B.E. Lawrence, 'Al-Beruni and Islamic Mysticism', in *Al-Beruni Commemorative Volume, op. cit.*, pp. 362-79.
70. E.C. Sachau, *op. cit.*, vol. I, p. 31.
71. *Ibid.*, p. 113.
72. Abū'l-Fazl'Allāmī, *A'in-i-Akbarī*. Tr. H.S. Jarrett, revised second ed., corrected and annotated by Jadunath Sarkar, vol. III, third edition, reprinted from second ed. (*sic*), Munshiram Manoharlal, New Delhi, 1978, p. 8.
73. E.C. Sachau, *op. cit.*, p. 21.
74. *Ibid.*, p. 40; italics original.
75. *Ibid.*, p. 249.
76. The *A'in-i-Akbarī* has exactly one paragraph each on Bauddha and Cārvāka beliefs, in a long chapter on Jaina beliefs which follows an equally long (but unilluminating) description of the nine systems of Indian philosophy. *A'in-i-Akbarī, op. cit.*, vol. III, p. 927.
77. Tibetan text and tr. in Hajime Nakamura, *A History of Early Vedānta Philosophy*, (English tr. Trevor Leggett *et al.*), Motilal Banarsidass, Delhi, 1983, Part 1, pp. 232-5. Ganganath Jha (tr.), *The Tattvasaṁgraha of Śāntarakṣita, With the Commentary of Kamalaśīla*, reprinted, Motilal Banarsidass, Delhi, 1986, vol. I, ch. VI, pp. 132-8. Ganganath Jha, p. 138, translates the commentary '"and others" is meant to include "Intelligent Time",' but this is immediately followed by 'There is a lacuna in the Text here.'
78. *Ibid.*, p. 237.
79. S.C. Vidyabhushan, *A History of Indian Logic*, Calcutta, 1921.

CHAPTER III

Glimpses of Mathematics in Medieval India

Wazir Hasan Abdi

I. ARITHMETIC

One of the greatest achievements of Indians in ancient times was the invention of the so-called decimal system of numeration. It consisted of three basic factors: 1. decimal base; 2. positional notation; 3. symbols for each of the ten numerals. It cannot be said with definiteness as to when the different symbols were invented. However, the earliest undoubted occurrence of zero appeared in India in a manuscript of AD 876.

The most difficult problem was giving names to the various numbers. Al-Beruni points out that Indian mathematicians used to express their numbers in words, but mathematics was restricted to Sanskrit scholars, and was committed to memory in the poetic form for example:[1]

- Zero was expressed as śunya-kha-gagana-ambara-ākāśa-antariksa, etc.
- One was denoted by ādi-śaśi-indu-vidhu-candra-kalādhara-soma-bhu, etc.
- Two was expressed by yama-netra-dṛṣṭi-cakṣu-nayana.
- Three was denoted by guṇa-triguṇa-trijagat-trikāla.
- Four was expressed by samudra-sāgara-dis-gati.
- Five was expressed by pañca-indriya, etc.

Similarly, different synonyms were used for the same numeral to suit the poetic necessity. For example, 1230 was written in at least three different ways:[2]

1. Kha-guṇa-kar-ādi.
2. Kha-lok-karṇa-candra.
3. Ākāśa-kala-netra-dharā.

It can be seen that while place-value is used here the order is from right to left.

It may be noted that since primitive times, numbers were an important medium of counting. In a pastoral civilization, heads of cattle were to be counted, but as agriculture, commerce and taxation required greater numbers, some standard measure of counting had to be evolved. But the most popular measure turned out to be ten,[3] 'as Aristotle had noted long ago, the widespread use today of the decimal system is but the result of anatomical accident that most of us are born with ten fingers and ten toes.' Orders of numbers were settled in terms of tens but, as Al-Beruni[4] pointed out, 'no nation got beyond thousand. The Arabs too stop with the thousand. Those, however, who go beyond the thousand in their numerical system are the Hindus. They extend the name and the orders of the numbers until

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the eighteenth order for religious reasons, the mathematicians being assisted by the grammarians with all kinds of etymologies.'

As long as the numbers were not very large, they were expressed in words, but when it came to dealing with large numbers, some sort of symbols had to be used. Other civilizations like Egyptian, Babylonian, Mesopotamian, or the Indus Valley had evolved their own systems, but the Chinese used symbols known as rod numerals whose precise age can not be determined. According to Boyer, they were used long before the positional notations were adopted in India. In Greece,[5] 'the alphabets denoted numbers: first nine letters represented 1 to 9 and then the next nine to ninety and the last nine from 100 to 900.' In fact the Greek alphabet contained only 24 letters. This would have implied that alphabetic numerals stopped at 600 only. Hence, by adding three archaic letters—*digamma, kappa, and sampi*—700, 800 and 900 were expressed. But then for numbers one thousand or above up to nine thousand, to the first nine letters of the alphabet, the positional number was added preceded by a stroke or accent. Later on, the Arabs in the eighth century adopted the system of alphabetic numerals based on Hebrew alphabets in Arabic script from 1 to 1000. However, there was no question of place-value in these systems. Numbers or their letter equivalent sums were expressed in words; for example, in Arabic 'Bismillah-ir-Rahman-ir-Rahim' was denoted by 786, which was obtained by adding the numerical values of its component letters. It cannot be said with definiteness as to when the reduction to 9 symbols occurred, but there is no doubt that the earliest occurrence of zero was not before the Christian era.

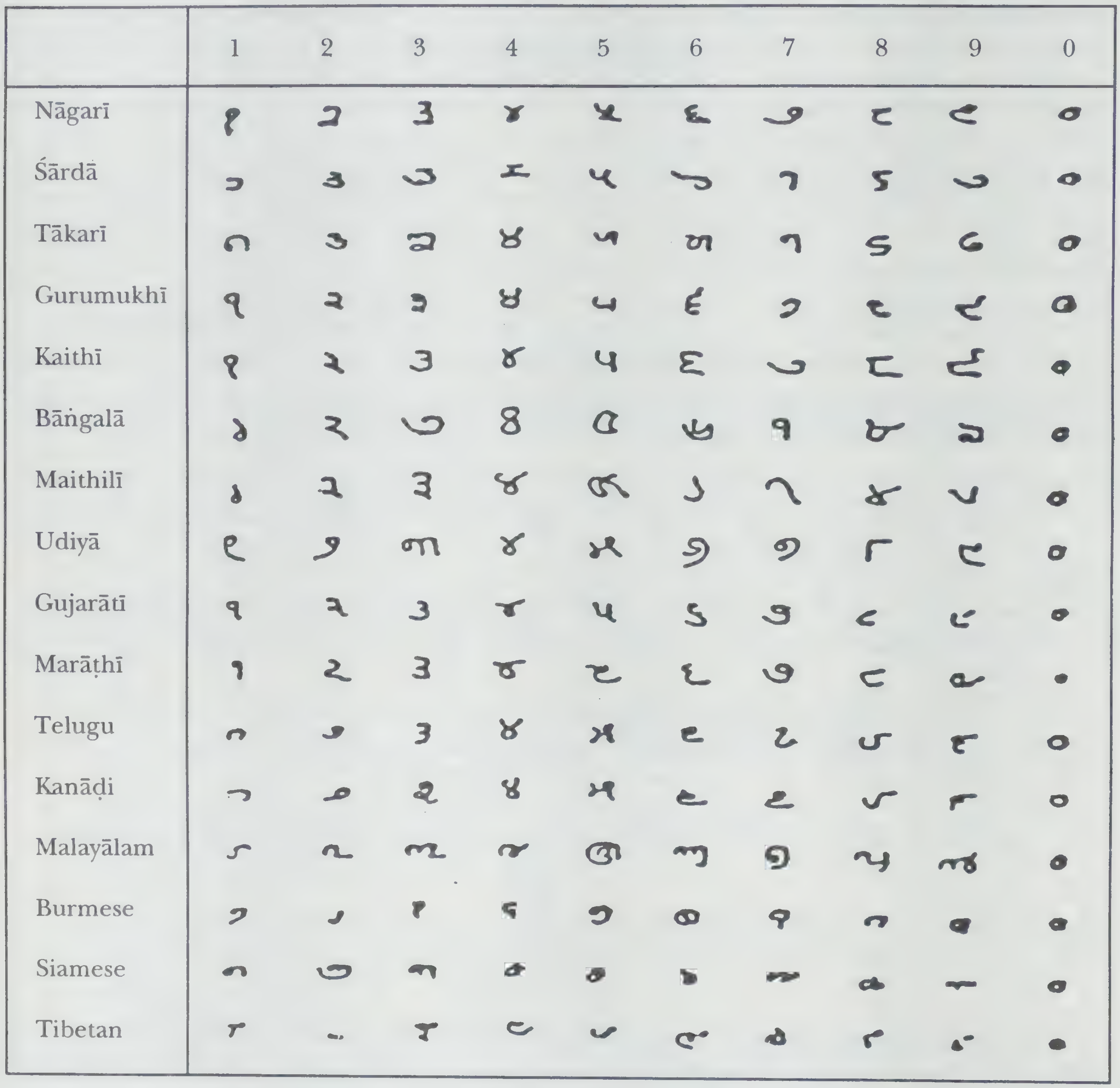
ا 1	ب 2	ج 3	د 4	ه 5	و 6	ز 7	ح 8	ط 9
ی 10	ک 20	ل 30	م 40	ن 50	س 60	ع 70	ف 80	ص 90
ق 100	ر 200	ش 300	ت 400	ث 500	خ 600	ذ 700	ض 800	ظ 900

غ
1000

Abjad Numerals

The positional concept of Sumerians and Babylonians[6] 'is imperfect because of the absence of zero and because the absolute value of the numbers quoted was often ambiguous.' The Sumerian numeration[7] was 'a strange mixture of decimal and sexagesimal systems. It would seem that their earliest mathematicians started with a decimal base but soon realized that a sexagesimal system would be better.... The system of numeration was thus mainly sexagesimal, for the symbol for 10 was subordinate and there was no symbol for 100, 1000, and so on. The absolute value of a number could be determined only from the context. They had no medial zero until later times. The absence of units of a certain order was indicated by an empty space and this was unclear and precarious. These ambiguities increased materially the difficulty of deciphering mathematical tablets.'

The gradual change from the old system without the zero and place-value is to be met in India alone.[8] All other nations had to give up their indigenous numeral symbols which they had used without place-value and adopted the zero and a new set of symbols. However, any reform howsoever useful takes time to be accepted universally. According to Heath,[9] 'the Greek alphabetic notation was invented in the seventh century BC, but took eight hundred years (second century AD) to be popular.' In Arabia, the new notation was introduced in the eighth century AD but it came into common use many centuries later.


1
2
3
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7
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Nāgarī
Śārdā
Tākarī
Gurumukhī
Kaithī
Bāṅgalā
Maithilī
Udiyā
Gujarātī
Marāṭhī
Telugu
Kanāḍi
Malayālam
Burmese
Siamese
Tibetan

Numeral Forms in Modern Indian Scripts

Alphabetic Notation and Word Numerals

It is worth noting that the decimal place-value notation and the word numerals were not invented at the same time. Āryabhaṭṭa-I (499)[10] used alphabetic system of notation for 'enumerating numerical data for his descriptive astronomy'. In this system, place-value was observed but numbers were written from left to right. For example, 1346 was denoted by *ta* (6), *tua* (4), *le* (3), *ke* (1). This system had many variants and continued to be used by Indian mathematicians up to the time of Āryabhaṭṭa-II (1150). These systems[11] 'unlike those employed by the Greeks or the Arabs, were never used by the common people, or for the purpose of making calculations; their knowledge was strictly confined to the learned and their use to the expression of numbers in verse.'

Word-numerals were extensively used by early mathematicians like Pulisa, Varāhmihira and Lalla. During the early stages of development (fourth century AD) appropriate words for the numbers were selected to fit in the meter. The selection of proper words would then naturally begin with the figure in the unit place and precede to the left. It was emphasized by the grammarians that prose and poetry should be written from left to right while the arithmetical notation should be written from right to left.

The earliest reference to place-value is found in Purāṇas. For example, *Agni Purāṇa* (first or second century AD) says that in case of multiples from the unit place, the value of each place (*sthāna*) is 10 times the values of the preceding place.

Writing of numbers in decimal arithmetic would have been imperfect without the introduction of zero. A casual reference is made in *Pañca Siddhāntika*[12] of Varāhmihira (505) but a description of decimal arithmetic of zero is found in Bhāskara-I's commentary on *Āryabhaṭṭīya* (525). Results about operations on zero have been elaborated in the work of Brahmagupta (628) and later writers. It is to be noted that the rules of operations on zero in Pāṭīgaṇita (arithmetic) are different from those in Bījagaṇita[13] (algebra). For example, Nārāyaṇa in his *Pāṭīgaṇita* says:, 'Here in pāṭīgaṇita, division by zero is not recognised and therefore, it is not mentioned here. As it is of use in bījagaṇita, so I have mentioned division by zero in my bījagaṇita.'

Āryabhaṭṭa, Śrīdhara and Āryabhaṭṭa-II agree with Nārāyaṇa that in pāṭīgaṇita[14] 'when zero is added or subtracted from a number, it (the number) remains unchanged, though (the number) multiplied by zero becomes zero. In multiplication and other operations on zero, the result is zero. When a quantity is added to zero, the result is that which is added'. In other words, if a is any positive integer, then:

$$a \pm 0 = 0$$
$$0 + a = a$$
$$0 - a = -a$$
$$a \times 0 = 0$$
$$0 \times 0 = 0$$
$$0 \div \mathrm{a} = 0$$

And when zero is divided by any non-zero number, the result is zero. But Mahāvīra (850) in his *Gaṇita-sārsaṁgraha* notes that[15] 'apart from the above operations, the number remains unchanged when divided by zero'. He probably thought that so far as arithmetic was concerned, division by zero was no division at all. As regards the use of zero in bījagaṇita, a detailed treatment can be found in Bhāskara-II's *Līlāvati.* According to him the concept of division of a non-zero number by zero is an infinite decimal. Earlier, Brahmagupta (628) treated[22] an infinitesimal quantity which became smaller and smaller and ultimately reduced to nought. The idea of zero as an infinitesimal is more in evidence in the works of Bhāskara-II. He had actually used a quantity which ultimately tended to zero, and found division by such a quantity of great use in astronomical calculations. The quotient of division by zero of a finite quantity was called kha'hara by Bhāskara-II, which is synonymous with kha-cheda (the quantity with zero as denominator) of Brahmagupta.

Regarding the value of the kha'hara, Bhāskara-II remarked:[17]

> In this quantity consisting of that which has cipher for its divisor, there is no alteration, though many may be inserted or extracted, as no change takes place in the infinite and immutable God, at the period of the destruction or creation of the worlds, though numerous orders of being are absorbed or put forth.

It may be noted here that the proofs of the rules of addition, subtraction and multiplication by zero are self-evident and can be verified by practical computation, because zero by itself has no value. It has definitely the property of increasing the value of a number ten fold if it is placed to the right of any non-zero number, e.g. 9 becomes 90, with two zeros it becomes 900, and so on. This idea was expressed in poetry by a Hindi poet Bihari in his *Sat-sai*, 'The bindi (symbol of zero) on the forehead of the maiden increases her beauty ten-fold.' And Tulsidas in his *Dohāvali* claimed that without a number (1 to 9), zero is meaningless, and said:

> Rāma nāma ek aṅka hai aur jagat sab śūnya,
> Aṅka binā saba śūnya hai aṅka saba dasa guṇā.
> (The name of Rāma is a number, and the universe is zero. Without number, all is zero and combined with number, it becomes ten-fold.)

The proof of Bhāskara-II regarding the value of kha'hara was based purely on religious faith. This was not peculiar to Indians. For example, Leibniz claimed that only two numbers, zero and one, were sufficient in mathematics because God was One and He created the universe ex-nihilo (from zero). This became the basis of modern binary system.

Trairasika

Apart from the usual operations of addition, subtraction, multiplication, squaring, cubing, extraction of square and cube roots, great importance was attached to the Rule of Three (Trairasika). In Trairasika three quantities were required: *p*, *ph* and *i*. The problem was: 'If *p* is *ph*, what will *i* yield?' Here *p* means pramāṇa (argument), *ph* means phala (fruit) and *i* means icchā (requisition). According to Āryabhaṭṭa-I, phala multiplied by icchā, divided by pramāṇa gives the solution. Various solutions of the problem were given by Brahmagupta, Siddhārta, Bhāskara-II, Nārāyaṇa and others. Here is an example of a problem:

> Out of 20 necklaces each of which contains 8 pearls, how many necklaces, each containing 6 pearls, can be made?

Trairasika was highly appreciated by other mathematicians of yore. For example Bhāskara-II[18] in *Līlāvati* said:

> As Lord Śrī Nārāyaṇa, who relieves the sufferings of birth and death, who is the sole primary cause of the creation of the universe, pervades the universe through his own manifestations as worlds, paradises, mountains, rivers, gods, men, demons, etc., so does the Trairasika pervade the whole of the science of calculation. Whatever is computed whether in algebra or in arithmetic by means of multiplication and division may be comprehended by the sagacious learned as Trairasika. What has been computed by the sages through the multifarious methods and operations such as miscellaneous rules, teaching its easy variations, is simply with the object of increasing the comprehension of the duller intellects like ourselves.

When Al-Beruni came to India, apart from the other works he composed *Al-Maqala fir Rashikat-ul-Hind*.[19] The problem of ratio and proportion had presented a difficulty to mathematicians. This was an interesting rule of computation introduced by Indians. Recently, Rosenfeld has translated Al-Beruni's *Rashikat* into Russian, with his own comments.

Internationalization of Indian Numerals

History tells us that a scientific discovery which originates in one country does not remain the sole property of that country. The same happened with Indian numerals. To the west of India, with the advent of Islam, a new interest in learning was being aroused. In Baghdad, a big scientific centre was being established by the Abbasid Khalifas, where[20] 'main attention was given to the studies of mathematics and astronomy. This was dictated by the requirements of trade (by caravan and sea), construction, irrigation and the immediate need of Moslem religion, that is, development of methods of determining the azimuths of Qibla and finding correct time for the beginning of prayers.'

At this centre, which was called Bait-al-Hikmah (House of Wisdom), worked scholars like Al-Kindi, an Arab, brothers Banu Musa from Iran, and Thabit-bin-Qurra from Syria. This group consisted of scholars from central Asia as well and was headed by Al-Khwarizmi,[21] who by birth was from Khwarizm. He was much closer to Indian culture, the roots of which went deep into centuries, to the epoch of the Kushan empire which united for long a considerable territory of central Asia and north India. The tradition of this culture was preserved for long in Khwarizm.

According to Volodavsky:[22]

> Among the treatises on practical arithmetic the pride of place belongs, from the point of view of chronology and impact on further development of science, to the treatise of the great central-Asian Al-Khwarizmi. He played the most important role in the spread of the place-value decimal system of calculation with the use of zero, which quickly gained popularity among the mathematicians, thanks to the evident advantages over the system of arithmetic. The arithmetic of numbers written down in this system were called Hisab-al-Hind (Indian calculation) or Indian arithmetic in central Asia and in the Near and Middle East. Up to the fourteenth century arithmetic calculations were usually performed with the help of a board covered with sand and dust, and intermediate results obtained in the process of calculation were wiped out, that is why Indian arithmetic was sometimes called 'calculation with the help of a board of dust'.

After Al-Khwarizmi,[23] the first mathematician to write was Ali-bin-Ahmad Nasavi (980-1040) who produced *Al-Muqna-fi-al-hisab'al-Hindi* (the desire-fulfilling book in Indian arithmetic). Many other books followed on the subject, although much earlier (i.e. in Khwarizmi's time) the Greek text *Arithmatica* (arithmetic) had already been rendered into Arabic. Even then, the importance of Indian arithmetic was in no way lessened.

It may be noted that in the beginning of the tenth century AD there was a lot of resistance to adoption of the decimal system, but west Asia, from Iraq to Spain, readily accepted the Indian numerals with place-value but without zero, and later on adopted the entire system. From Spain, the Indian discovery travelled to Europe after seats of learning were established at Qartaba (Cordova) and Gharnata (Granada), where students from all parts of Europe were attracted. There, scholars learnt Indian numerals and found them far superior to the Roman numerals. But the man mainly responsible for spreading Indian system to Europe was Leonardo Fibonacci. According to Suleman Nadvi:[24]

> He wrote his *Liber Abaci* in 1220, revised it in 1228. At first his book met with cold reception from the public because it was too much for the merchants and too novel for the universities... A most determined fight against the spread of these numerals was put up by the abacists who did not use zero but employed an abacus and the apices. But the writings of men like Leonardo succeeded in silencing them although it took two or three centuries to do so. By the middle of the fifteenth century we find that these numerals were generally adopted by all the nations of western Europe, but they came into common use only in the seventeenth century.

It may be noted that, many great theories of philosophy that originated in India were preserved in some Indian classics only, although they deserved to be made known all over the world. The Arabs were the agents of spreading Indian numerals to the entire world but were honest enough to call them Indian numerals, while Europeans wrongly believed them to be

Arabic. In this connection mention may be made of Abu Raihan Al-Beruni, the first important Indologist. He visited India at a time when Mahmud of Ghazni was plundering the country, destroying and terrorizing the people. But Al-Beruni settled down to study the classical arts, science and literature of India. Like a genuine scientist, he faced all kinds of difficulties in acquiring the language from Pandits, discrimination being rampant not only against foreigners but also against Indians on the basis of varṇa. He translated a number of Indian classics on philosophy, mathematics, astronomy, geography and other physical sciences from Sanskrit into Arabic. Of the treasures that he left, there are twenty-one volumes, among which the compendia titled *Kitab al-Hind* and *Qanoon-e-Masudi* are the most important. Later, *Kitab al-Hind* was translated by Edward Sachau and still remains an important reference book on early Indian mathematics.

However, when Muslims started establishing their kingdoms in India, initially they did not appear to have taken advantage of Al-Beruni's translations, which were original from Sanskrit works. The first Sultan of Delhi was Firoze Shah Tughlaq who got Varāhmihira's *Bṛhat-saṁhitā* translated by Abdul Aziz Shams Baha Nuri Dehlavi. The translation does not contain chapters which were supposed to be in praise of Hindu gods, but it contained the description of auspicious times for coronation of kings, building of palaces, principles of architecture, and the formula for finding subsoil water.

On the other hand, some Arabic works on astronomy and astrology were also translated into Sanskrit under the patronage of Firoze Shah Tughlaq by Mahendra Suri and later Malayendra Suri. Similarly, a Persian work, *Tibb-e-Firoze Shahi*, was compiled by Hakim Bahwah giving the principles of Āyurvedic medicine as enunciated by Āyurvedic classics.

It appears that the first Indian mathematician who wrote a book on arithmetic in Persian was Haji Abdul Hamid Ghaznavi. In 743 (AD 1342) he thought of writing a treatise entitled *Dastur-i-albab fil, ilm-al-hisab*, primarily for training his son Badruddin Abul Fath; because during Muhammad Tughlaq's reign a good training in arithmetic was supposed to be a gateway to high posts in government or even in religious affairs. The book was divided into five sections and consisted of thirty-two chapters and one hundred and sixty articles. Most of the formulae were given in verse. Numbers were not given in the Arabo-Persian alphabetic script, but in Arabic form of Indian numerals; sometimes the script current in use by officials and traders was used. The book[25] opened with the usual hymn to God, praise of Prophet Muhammad and the first four Khalifas of Islam. The author then described the importance of mathematics as a secular and spiritual affair and as the only science which had no scope for difference of opinion while even religious subjects could not be free from controversies. Mathematics was required by medical practitioners for prescribing various proportions of medicinal ingredients, by judges to determine the quantities of inheritance, by religious leaders to determine the direction of Qibla (Ka'ba, the great shrine at Mecca), and by traders and state officials for the purposes of weights and measures. He advised his son[26] 'to study mathematics with a master as it is consistently difficult. But if you spend time in acquiring proficiency in this art, then glory and authority will be in your hands.' He attached great importance to exact definition of technical terms and emphasized the importance of reading and in this connection traced the history of alphabets. He presented elaborate descriptions with examples of arithmetical operations like addition, subtraction, multiplication and division (but avoiding division by zero), halving, doubling, squaring, cubing, and fractions including their properties and unit.

On the whole, like mathematics of western Asia, arithmetic was based on Pythagorean principles.[27] For example, according to Ghaznavi, 'One is not counted amongst numbers. One is God, the creator, a number (positive integer) is half sum of its hashias (predecessor and successor). No number comes into use without them.' He discussed the properties[28] of triangular, square and cubic numbers and other principles as defined by Pythagoras but, strangely, did not mention the name of Pythagoras. He also gave multiplication tables, principles and details of ratio-proportion and *regula falsi* with examples, besides emphasizing unit fractions and the process of halving, doubling, squaring and cubing of numbers.

As arithmetic was the main tool for assessing and realizing taxes and for calculating areas of rectilinear figures, Ghaznavi gave general principles of ratio-proportion, volumes of common solids, details of taxable items, their weights and rate of taxes, besides a detailed description of weights and measures of all types in use in India at that time. This seemed to be a common feature of all texts on arithmetic during those centuries.

The book was meant as a guide to the author's son for entering government service. Many chapters were devoted to describing the qualities expected of high government officials. For example, according to the author[29] 'the *wazir* (King's first minister) should adore himself with learning as it would be the capital of both the worlds. He should not incline towards merriment. He should read the stories about past wazirs extensively and in most matters consult people of high ranks and traders. He should not be proud of his own wisdom.' He advised the *musharraf* (a high-ranking revenue official)[30] 'to know that the difference between the solar and lunar year is $10 + \frac{1}{2} + \frac{1}{5} + \frac{1}{6} \left(= 10\frac{13}{15}\right)$ days. Accordingly, 33 solar years are equal to 34 lunar years. If the *musharraf* does not know this, he will collect revenue from peasants for 68 half years while the actual number of years will be 66. This amounts to extortion and exploitation of the poor, while if taxes are collected from the rich according to solar calendar, the treasury will lose two half years' taxes. The official should not be guilty of extortion or of causing loss of income to the government.'

Textbooks and Commentaries

It may be mentioned here that no arithmetical text by any Indian author in Persian or Arabic was current in Arabic-Persian medium madrasahs. However, when Akbar occupied the throne, he issued a *firman* about his educational policy which read:[31]

> Every boy ought to read books on morals, arithmetic, the notation peculiar to arithmetic, agriculture, mensuration, astronomy, physiognomy, logic, higher mathematics, science and history, all of which may be gradually acquired.

When Fath Ullah Shirazi joined Akbar's court, emphasis on rational sciences increased. In this new syllabus, study of some small booklets in mathematics was made compulsory for the students. For this purpose, he got *Līlāvati* of Bhāskarācārya translated into Persian by Faidi (1587). However, it could not become a popular text in madrasahs. It is interesting to note that in AD 1658-07 in the reign of Aurangzeb, Midni Mal composed *Bada'i Kulli* based on *Līlāvati* and divided it into nine chapters. At the same time, Valmiki Tiwari wrote a treatise based on *Līlāvati*, translated it into Persian and called it *Vikaṭa Cintāmaṇi*, retaining the Sanskrit title. It begins with 'Bismillah-ir-Rahman-ir-Rahim' followed by a brief Maṅgala Caraṇa. Most of the examples were from *Līlāvati* or of the same type. Not many commentaries or glosses were composed in Persian but a number of texts based on it did appear, of which at least six are mentioned by Storey.[32]

In Sanskrit also, not many texts were written; mostly commentaries were composed. For example: *Budh Vilāsani* by Daivajya and *Līlāvati Vivaraṇa* by Mahi Dhar, which was elaborated by Nārāyaṇa Paṇḍita as *Gaṇita Kaumudi*. Śrīdhar wrote *Sarva Bodhini Vyākhyā* in 1717. Mahi Dhar's *Līlāvati Vivaraṇa* came in 1722, and Nilambara Jha brought out *Dalita Līlāvati Udāharaṇa* in 1825. Thus *Līlāvati* (one or the other text) and its commentaries continued to be the main text of arithmetic in Sanskrit.

One of the main reasons why Faidi's translation of *Līlāvati* could not become popular in madrasahs was that the scholars had stuck to the Pythagorean brand of arithmetic.

Accordingly, for this purpose, an assortment of texts mostly in Arabic were current. However, Baha-ud-din Amuli (1547-1622) composed a mathematical text in Arabic entitled *Khulasat-al-Hisab* laying down the fundamentals of arithmetic in a nutshell; it dealt with arithmetic, mensuration, algebra and trigonometry, illustrating their applications throughout on the basis of inheritance, legacies, trade and commerce. It continued to be a part of madrasah education right up to the later part of the century. A text neither in Sanskrit nor in Arabic was also taught. Soon after it was introduced, commentaries began to be written on it in Arabic and Persian. The first commentary written by an Indian was *Anwar al Khulasat al-Hisab* by Ismat Allah Saharanpuri in 1670. Lutf Allah Muhandis bin ahmad Mi'mar wrote two commentaries—one in Arabic on which his elder son Imam al-Din wrote a super commentary, the other in Persian entitled *Muntakhab* in 1681. Amin al-Din Ahmad al-Lahori (d. 1780), Khwaja M. Mah (eighteenth century), M. Zaman Fayyad (eighteenth century), Maulana Ataullah, Mirza M. Beg, Nizam al-Din Ahmad bin M. Abdullah Ashashahid and Raushan Ali Jaunpuri (early nineteenth century) wrote commentaries mostly in Persian. An Urdu commentary was also written by Ghulshan Ali Jaunpuri in 1871. These commentaries might not necessarily have original arithmetical thought, but surely presented new methods of operations and interpretations. For such works, Sarton[29] has commented:

> Creations absolutely de novo are very rare, if they occur at all; most novelties are only novel combinations of old elements and the degree of novelty is thus a matter of interpretation.

Encyclopaedic Works

The nineteenth century was a period of compendium writing. In Persian, such a work entitled *Khazinat-al-ilm* was written by Diwan Kanhimal Kayasth 'Azimabadi' in 1229 (1814), which was dedicated to Francis Hawkins. This work consisted of ten chapters mostly dealing with arithmetic, mensuration and algebra. Abd al-Rahim Gorakhpuri, commonly called Abd al-Rahim Dahriyah, composed an encylopaedic work entitled *Shigarfi Bayan* in the first quarter of the nineteenth century, which dealt with (i) a history of the genesis and evolution of the human race; (ii) a brief autobiography; (iii) an Arabic treatise on astronomy; (iv) five important reasons for translating into Arabic and Persian the standard European works on astronomy, geography and arithmetic; and (v) reasons for preferring the work of Simpson to that of Nasir al-Din Tusi on Euclid's *Elements.*

Another important compendium was Ghulam Husain Jaunpuri's *Jame-i-Bahadur Khani.* Called the 'Encyclopaedia of Mathematical Sciences', it occupied an important place in mathematical literature. It was written on the instructions of Mirza Khan Bahadur, son of Rajah Mitrajit Singh of Tikari, a principality in Bihar. In fact, the whole seven hundred and twenty page book covering various branches of mathematics, astronomy and optics was completed in less than fifteen months. In the introduction he gave the reasons for writing this book in the following words:[33]

> Once Rajah Khan Bahadur Khan, illustrious son of Maha Rajah Mitrajit Singh of Tikari, addressed me saying that during these days mathematical sciences and arts, in spite of elegance of problems, firmness of arguments and pleasure due to confirmation and deriving benefits have been so much out of fashion and forsaken that not even one among the elite and the commoners in our regime has any inclination towards it. This is not free from a few reasons: Firstly, they do not know its importance and objective, so they could not turn towards it. Secondly, from the reading and study of the books on this art, it is clear that the acceptance of prepositions to the extent of belief is dependent on the existence upon a large number of books and treatises such that some depend on another, besides they are not free from such positions and difficulty of words and

> obscurity of meaning. Hence non-availability of these scientific books and also the huge volume and the toughness of expression becomes forbidding for most of the people. Thirdly, although rational sciences have no particular language but most of the books on these sciences through which maximum benefit can be obtained are in Arabic. Therefore, majority of the Persian knowing scholars who have not spent much of their time in learning Arabic remain deprived and it is also known that by rational contemplation, the problems become finer and better day by day.

Jaunpuri's compendium consisted of (i) geometry (Euclidean), one, two and three dimensions, and mensuration; (ii) principles of optics; (iii) trigonometry; and (iv) elements of astronomy, besides principles of arithmetic and various operations of decimal and sexagesimal fractions. Interestingly, table of logarithms[34] were also given in *Jame-e-Bahadur Khani*. The author seemed to be much ahead of his time. He also gave eighteen summation formulae for arithmetic and geometric series of integers, squares and cubes, many of which he claimed to be original. He tried to give a lead to Indian mathematicians of Persian stream, not only to look backwards but also forward, and tc accept a good idea no matter what its source.

II. ALGEBRA

The earliest mention of an Algebraic problem appears to be in *Satpathi Brāhmaṇi* (*c.* 200 BC) in connection with the construction of a fire altar for sacrifices to achieve special objects. This could give rise to an algebraic equation. Similarly, problems of altar objects gave rise to equations of second degree, and also simultaneous indeterminate equations up to four variables of the first degree. However, the solutions were obtained using geometrical methods. The popular name for algebra was *bīja* (element of analysis) and *gaṇita* (science of calculation). The name *bījagaṇita* first appeared in the works of Prthudakasvami (860) and Nārāyaṇa (1350). According to Bhāskara-II,[1] 'Algebra is computation attended with demonstration, else there would be no distinction between arithmetic and algebra.' In *Bījagaṇita* he mentioned two methods of demonstration in algebra—geometrical (*kṣetragata*) and symbolic (*rāśigata*). He felt that geometrical methods could be ascribed to ancient sages.

As was customary with early mathematicians to invoke god in their scientific pronouncements, Bhāskara-II stated:[2]

> What the learned calculators (*sāṁkhyah*) describe as the originator of intelligence being directed by a wise being (*satpuruṣa*) and which alone is the primal cause (*bīja*) of all known (*vyakta*), I venerate that Invisible God as well as that Science of Calculator with the Unknowns... since questions can scarcely be solved without the reasoning of algebra—not at all by those of dull perceptions.

And later Nārāyaṇa[3] (1350) in his *Bījagaṇita* asserted:

> I adore that Brahma, also that Science of Calculation with the unknown, which is the one invisible root-cause of the visible and multiple qualitated universe, also of multitudes of rules of the Science of Calculation with the Known.

Further, he stated:[4]

> As out of Him is derived this entire universe, visible and endless, so out of algebra falls the whole of arithmetic with its endless varieties (of rules). Therefore, I always make obeisance to Śiva and also to (*avyakta*) gaṇita (algebra).

An important difference between the properties of numbers of arithmetic and algebra can be found in the writings of certain Indian mathematicians, but Bhāskara-II stated:[5]

> The square of a positive and negative number is positive; the square-root of a positive number is positive as well as negative. There is no square-root of a negative number because it is non-square.

And Nārāyaṇa emphasized:[6]

> The square of a positive and negative number is positive. The square-root of a positive number will be positive and also negative. It has been proved that a negative number, being non-square, has no square-root.

It may be mentioned here that in modern mathematics, negative numbers also have two square-roots and both square-roots will be imaginary. For example, the square-root of 4 is ± 2 while the square-root of -4 will be $\pm\sqrt{-4}$. Another difference is in the division of any number by zero which is not permissible and leads to errors. However, in algebra any quantity divided by zero has a definite meaning.

Kṛṣṇa elaborated thus:[7]

> As much as divisor is diminished, so much is the quotient increased. If the divisor is reduced to the utmost, the quotient is to the utmost increased. But if it can be specified, that the amount of the quotient is so much, it has not been raised to the utmost for a quantity greater than that can be assigned. The quotient, therefore, is indefinitely great and is rightly termed infinite.

He says that $a/0 = b/0$ is proved by the shadow of a gnomon which at sunrise and sunset is infinite and is equally so whatever height be given to the gnomon.

Linear equations with one variable have been considered by Bhāskara-II in *Bījagaṇita* besides others. Linear equations with two unknowns which include simultaneous linear equations have been tackled by quite a few mathematicians. Also linear equations with several unknowns are claimed to have been mentioned as early as in Bakshali manuscript and by Brahmagupta, Prthudakasvami and Mahāvīra. A few problems have been solved even by Bhāskara-II in *Bījagaṇita.*

Indian mathematicians specially Śrīpati (1048) and Bhāskara-II (1150) paid special attention to quadratic equations and Jñānrāja (1503) described some methods of solving the quadratic equations like Bhāskara-II. It was observed that a quadratic equation has generally two roots. In this connection Bhāskara pointed out, with the help of a few specific examples, that the two roots were theoretically correct but care ought be taken in accepting one of them. He considered the problem thus:[8]

> The fifth part of a troop of monkeys, leaving out three, squared, has entered a cave; one is seen to have climbed on the branch of a tree. Tell how many are they?

In modern symbols the problem amounts to the quadratic equation $x^2 - 55x + 250 = 0$. The solution here will be 50 and 5 but Bhāskara says that 'the second value will not be accepted as it is inapplicable. People have no faith in the known becoming negative. If the monkeys are only 5, there will be only one monkey. However, can one then leave out 3 monkeys?

Another example is contained in *Bījagaṇita*, wherein Bhāskara poses a problem thus:

> The shadow of a gnomon of 12 fingers being diminished by a third part of a hypotenuse becomes equal to 14 fingers, mathematician tell it quickly.

The solution lies in the quadratic equation $8x^2 - 252x + 1620 = 0$. Accordingly, the value of the shadow is $\frac{45}{2}$ or 9. The value 9 being less than 14 will not be accepted.

Earlier also Mahāvīra (850) and Brahmagupta (628) had come to the conclusion that a quadratic equation has two roots but only one was to be retained due to practical considerations.

Cubic and Biquadratic Equations

As pointed out by Datta and Singh, 'The Hindus did not achieve much in the solution of the cubic and biquadratic equations.' Bhāskara-II (1150) attempted[10] to apply the madhyama dharana (elimination of the middle) but observed, 'Due to the presence of the cube, biquadratic, the work (of reduction) cannot proceed any further, after the performance of such operations, for want of a root of unknown side (of an equation), then the value of the unknown must be obtained by the ingenuity (of the mathematician).'

However, he considered the equation $x^3 - 6x^2 + 12x - 35 = 0$ and got his solution as $x = 5$. He also tried biquadratic equation and attempted only one solution, and he then stated[11] that 'in similar instances value of the unknown must be determined by the ingenuity of the mathematician', but did not lay down any general rule.

It may be mentioned here that an illustrious contemporary of Bhāskara-II was the Persian mathematician Omar Khayyam (1050-1123), whom the west only recalls, according to Boyer,[12] as one of the greatest Persian poets. He attempted equations of third degree as well and provided for quadratic equations by geometric solutions. He believed that arithmetic solutions were impossible. Hence he gave only geometric solutions. His claim of using intersecting were used earlier by some Greek mathematicians. But Omar Khayyam took the wise step of using geometric methods to cover all third degree equations having positive roots. When in earlier works he came across a cubic equation, he specifically remarked, 'This cannot be solved by plane geometry (i.e. using straight-edges and compasses only) since it has a cube in it. For the solution, we need conic sections.'

Omar Khayyam was very clear about his methodology in algebra and he wrote:[13]

> Whoever thinks algebra is a trick in obtaining unknowns has thought it in vain. No attention should be paid to the fact that algebra and geometry are different in appearance. Algebras are geometric facts which are proved.

Indeterminate Equations

There was one area in mathematics in which Indians contributed much more than anyone else, and that was the treatment of indeterminate equations. The equation, $by - ax = c$, where a, b, c are integers, is known as the first degree simple indeterminate equation. Although this type of equation was attempted much earlier by the Greek mathematician Diaphantos, it was Āryabhaṭṭa-I (b. 476), who gave a method for finding a general solution. His disciple Bhāskara-I showed that the same method could be applied to solve $by - ax = -c$. As Boyer pointed out:[14]

> Brahmagupta evidently loved mathematics for its own sake, for no practical minded engineer would raise questions such as those Brahmagupta asked about quadrilaterals. One admires his mathematical attitude even more when one finds that he was the first one to give a general solution of the linear Diaphontine equation $x^2 = 1+ py^2$ which is named mistakenly after John Pell (1611-1685) but first appearing in the Archmedian cattle problem. Bhāskara gave particular solution for 5 cases of $p = 8, 11, 32, 61$ and 67. For $x^2 = 1 + 61y^2$ equation, he gave the solution $x = 1, 776, 319$ and 049 and $y = 22, 615$

and 319. This is an impressive feat in calculation and its operations will only tax the efforts of the reader.

The method of solving an indeterminate equation is known as the 'pulverizer', and the same method has been suggested for solving a linear equation in more than two unknowns as well as simultaneous indeterminate equations of the first degree. Bhāskara-II gave an example in *Bījagaṇita*[15] for the following problem:

> The numbers of flawless rubies, sapphires and pearls with one person are, respectively, 5, 8 and 7, and his friend has another 7, 9 and 6, respectively, of the same gems. In addition they have coins to the extent of 90 and 62. They are thus equally rich. Tell quickly O intelligent algebraist the price of each gem.

For solution, in modern notation, let x, y and z represent the price of rubies, sapphires and pearls, respectively, such that $5x + 8y + 7z + 90 = 7x + 9y + 6z + 62$. By the method of pulverizer, we get $x = 14 - m$ and $y = 2m + 1$ where m is an arbitrary number. Putting $m = 0$, 1, 2, 3... we get the value of (x, y, z) as (14, 1, 1), (13, 3, 1), (12, 5, 1), (11, 7, 1), etc. Bhāskara-II then observes, 'By virtue of a variety of assumptions multiplicity of value may then be obtained.'

Varga Prakṛti

An important type of indeterminate quadratic equation is $Nx^2 + 1 = y^2$. Such an equation is called *varga prakṛti* (square nature). It has been conjectured by Datta and Singh[16] that the name 'varga prakṛti' originated from the following consideration:

> The principle (prakṛti) underlying the calculations in this branch of mathematics is to determine a number (or numbers) whose nature or the simple number (or numbers) after certain specified operation will yield another number (or numbers) of the nature of a square.

Much earlier than Fermat (1657), Śrīpati (1039) observed that if N is a non-square integer the varga prakṛti $Nx^2 + 1 = y^2$ will have an infinite set of two roots. Bhāskara-II (1150) remarked[17] that, 'The roots are infinite by virtue of (the infinitely repeated application of) the principle of composition as well as of (the infinite variety of) the optional value (of the first root).' Nārāyaṇa (1350) wrote[18] that, 'By the principles of composition of equal as well as unequal sets of roots (will be obtained) an infinite number of roots.'

Indian mathematicians starting from Brahmagupta (628) devoted much attention to the solution of the indeterminate quadratic equation $Nx^2 \pm c = y^2$ where N and c are positive integers. For example, Bhāskara-II mentioned in his *Bījagaṇita*:[19] 'In (a square nature) with the additive or subtractive greater (than unity), one should find two roots by his own intelligence only; then by their composition with the roots obtained for additive unity an infinite number of roots (will be found)'.

However, Bhāskara-II examined the form $Nx^2 - k^2 = y^2$ and observed[20] that, 'When unity is the subtractive, the solution of the problem is impossible unless the multiplier is the sum of two squares.' However, if $N = m^2 + n^2$, two rational solutions of $N x^2 - 1 = y^2$ are:

$$\text{(i) } x = \frac{1}{n},\ y = \frac{m}{n} \text{ and (ii) } x = \frac{1}{m},\ y = \frac{n}{m}$$

So, two rational solutions of $(m^2 + n^2)\,x^2 - k^2 = y^2$ will be

$$\text{(i) } x = \frac{k}{n},\ y = \frac{km}{n} \text{ and (ii) } x = \frac{k}{m},\ y = \frac{kn}{m}.$$

Single Indeterminate Equation of the Second Degree

Hindu mathematicians of the medieval period contributed a lot to the solution of indeterminate equation of the second degree, namely, $ax^2 + by^2 + c = z^2$. Apart from Bhāskara, Kamalākar[21] (1658) considered at least two types of equations: (i) when c is not a square, and (ii) when c is a square. Kamalākar assumes the solution of $x^2 + by^2 + d^2 = z^2$ as: $x = \frac{by^2}{2ad}$ and thus on computation $z = \frac{by^2}{2d} + d$. But when c is not a square, two numbers p and q are such that $c = q^2 - p^2$, and then on computation, x turns out to be:

$$x = \frac{by^2}{2a\,(q-p)} + \frac{p}{a}$$

and $$z = \frac{by^2}{2\,(q-p)} + q$$

Besides Mahāvīra, Bhāskara (1150) and Nārāyaṇa (1350) had given methods for solving indeterminate equations for higher degrees.

Double Equation of the First Degree

As early as 628, Brahmagupta[22] had solved and given the general solution of $x + a = y^2$ and $x - b = u^2$ as

$$x = \left\{\frac{1}{2}\left(\frac{a-b}{m} \pm m\right)\right\}^2 + a$$

and $$x = \left\{\frac{1}{2}\left(\frac{1-b}{m} \pm m\right)\right\}^2 + b$$

Nārāyaṇa[23] describing the method stated:

> The sum of the two numbers by which another number is (severally) increased and decreased so as to make it a square is divided by an optional number and then diminished by it and halved; the square of the result added with the subtrahend is the other number.

He further said:

> The difference of the two numbers by which another number is increased twice so as to make it a square (every time) is increased by unity and then halved. The square of the result diminished by the greater number is the other number.
>
> That is, $x = \left(\frac{a-b+1}{2}\right)^2 - a$ is a solution of $x + a = u^2$, $x + b = v^2$, $a > b$.

The mathematicians also tried and gave methods for solution of cube pulverizers, double equations of the second order, multiple equations, and the like. Some of the results and principles have been given in modern notations by Bibhuti Bhushan Datta and Avadesh Narayana Singh in *History of Hindu Mathematics: Part II*. As the original mathematicians wrote their formulae in words, the authors have explained the principles in modern notation. But one thing is very clear: the Indian mathematicians were far ahead of the European mathematicians like Euler (1764), Lagrange (1768) and others.

It has been noted that[24] the equation $61x^2 + 1 = y^2$ was first proposed by Fermat to Frenicle in a letter written in February 1657. And Euler solved it in 1732.

From 'Bījagaṇita' to 'Algebra'

The two texts, *Bījagaṇita* of Bhāskara-II and *Gaṇita Kaumudi* of Nārāyaṇa, were the most representative texts of algebra by Indian mathematicians. In fact, Bhāskara's *Siddhānta Śiromaṇi* consisted of two parts—*Līlāvati* dealing with arithmetic and *Bījagaṇita* dealing with algebra. *Līlāvati* attracted the attention of Akbar, who was very keen on the advancement of learning. He issued a firman making the study of certain subjects including arithmetic compulsory in schools. For this purpose he got *Līlāvati* translated into Persian by Faidi (AD 1587). However, it took 68 years to get *Bījagaṇita* translated by Ataullah Rushdi as *Tarjumah-e-Bījagaṇita*, which was dedicated to Shah Jahan. This translation[25] 'is particularly important because when Edward Strachey was studying Indian algebra, he got a copy made and translated it into English with notes by S. Davis. It was published in AD 1813 in London as *Bījagaṇita or the Algebra of the Hindus.* Another English translation by H.T. Colebrooke appeared four years later under the title *Algebra with Arithmetic and Mensuration* from the Sanskrit texts of Brahmagupta and Bhāskara; it contains translation with notes of a part of *Bījagaṇita.* This means that Europe came to know about Indian classics first through Persian translation.

It is interesting to note that while Indian numeration mathematics reached Europe through Arabic translations, Indian algebra reached there through Persian.

But what is the origin of the word 'algebra'? Undoubtedly, Europe came to know about it from the treatise of Musa Al-Khwarizmi (*c.* 780-850), entitled *Kitab-e-Mukhtasar fi Hisab al-jabr wal Muqabala* (A Short Book on the Calculations of Al-jabr and Al-muqabalah). Cardano and Tartaglia of sixteenth century Europe regarded Al-Khwarizmi as the inventor of algebra. There is much confusion amongst historians about the original source of Al-Khwarizmi's knowledge; some have suggested that it is Greek, others have claimed that it is Indian. In this controversy, Colebrook has come to the conclusion[26] that:

> We were well assured that the Arabs mediately or immediately were our instructors in this study. But the Arabs themselves scarcely pretend to the discovery of algebra. They were not in general inventors but scholars during the short period of their successful culture of the sciences; germ at least of the algebra analysis is to be found among the Greek in an age not precisely determined, but more than probably anterior to the earliest dawn of civilization among the Arabs.

So the question as to the source of Khwarizmi's algebra still remains open. Summing up the arguments on both sides G.P. Matvievskaya[27] agrees with Karpinski that:

> Algebra is not an artificial achievement of human inventions but rather a material manifestation of man's interest in numerical aspect of the world of ideas and developed according to the laws of inner logic and to a great extent independently in mathematics of Egypt, Babylon, China, Greece and India.... More important is the fact that algebraic aspect of mathematics possesses inner interest in human mentality, not determined either by time or place but depending merely on the development of thinking abilities. Al-Khwarizmi's activities, whom I. Ch. Karpinsky calls great mathematician, signifies the beginning of the period in the history of mathematics in which analysis rose to the level of geometry. He does not deny the fact that in Al-Khwarizmi's algebra ideas of predecessors are synthesized.

Algebra in Madrasahs

In Indian madrasahs where Arabic and Persian were the medium of instruction, algebra was not treated as a separate subject. It was only a part of textbooks on hisāb (arithmetic). The most popular text was one *Khulasat-ul-Hisab* by Bahauddin Amuli, an astronomer and encyclopaedist of the sixteenth century. It is interesting to note that although Faidi's translation of *Līlāvati* and Ataullah Rashdi's translation of *Bījagaṇita* in Persian were available, these were not made use of in the madrasahs. *Khulasat-ul-Hisab* was popular as it covered a wider range of mathematics.

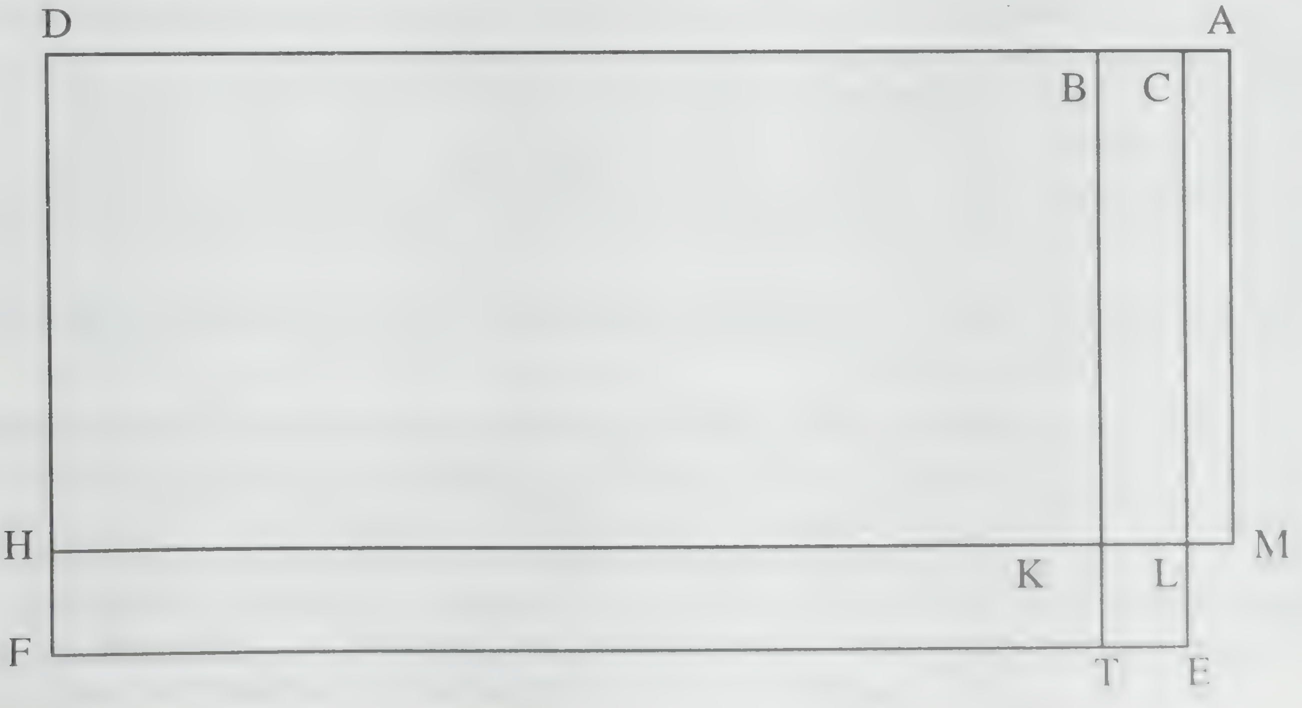
A number of commentaries were also written in Persian by Indians[28]—Asmatullah Saharanpuri (1670), Lutf Allah Muhandis, Imaduddin (1681), Aminuddin Ahmad Lahori (1780), Khawaja Mohammad Mah (eighteenth century), Ataullah Nizamuddin Ahmad, Raushan Ali and many others. An Urdu commentary was also written by Gulshan Ali Jaunpuri (1871). Though these commentaries were not necessarily the result of original mathematical thought, they did present some new methods of operation and interpretation.

Method of Forming Equations

Obtaining solutions by al-jabr-wal-muqabala depends upon penetrating insight, deep thinking and intelligent study, devoting one's thoughts to what is given by the questioner and applying the mind so as to lead to what is required through the available sources.

Suppose the unknown is the *shai* and you have to proceed according to what is given in the problem till you arrive at an equation. Complete the side of exclusion and add likewise on the other side, and this is al-jabr (restoration or completion); now remove similar terms of same type from both sides and this is muqabala (reaction or balancing).

Then a question is formed with *jins* and *jins* and there are three problems called simple or a *jins* and two *jins* and there are three other called *muqtaran* (conjunctive). The three *mufrads* equations which are formed with *jins* and *jins* in modern notation are: (i) $ax^2 = b$, (ii) $ax^2 = bx$ and (iii) $ax^2 = b$, and the three *muqtarans* (conjunctive equations) in which one *jins* equals another *jins* is expressed in the notation form: (iv) $ax^2 + bx = c$, (v) $ax^2 + c = bx$, and (vi) $ax^2 = c + bx$, where a, b and c are positive integers. The *mufrads* are comparatively easy but for the solution of the *muqtarans* a description is given and for each quadratic equation, a separate formula has been evolved. However, no proofs are given and only the positive roots are taken. As already mentioned, in the early nineteenth century, an Indian mathematician Ghulam Husain Jaunpuri gave a geometrical[30] solution of the quadratic equation $ax^2 + bx = c$, a, b and c being positive integers.



Let us now consider the above figure. We say that the square BH is the *mal*, the surface AK is the *ashia*, the line AB is the number of *ashia*, LT is the square of half and the number of *ashia*. So, the surface AH comprises a *mal* and *ashia* or with the square LT with square CF. Since the number equals the sum of *ashia* and *mal*, if we increase over it the square of the half of the number of *ashia*, then square number will be obtained equal to the square CF. Square-root of this number is equal to the side CD when the square-root of the half of the number of *ashia* which is CB is subtracted, the remainder BD which the square-root of the *mal* BH. We may note that this figure corresponds to only one solution of the quadratic equation.

Bahauddin takes ten problems of different types which according to him[31] 'sharpen the mind of the students, involving numbers, filling of pipes, business connection and height and distance, and the like. He finds solutions of every problem by regular falsi, by analysis and by algebra,' and shows that one method is as good as the other.

Indian mathematicians and students of mathematics attached to madrasahs, where the medium of instruction was Arabic and Persian, found that the six types of equations were sufficient for their need. It may be noted that an Indian mathematician of the eighteenth century, Najm-uddin Thaqib, wrote about the six equations—three *mufrads* and three *muqtarans*—in Persian verse in the tradition of Indian mathematicians like Bhāskara and others, and gave some examples in prose.

It is noteworthy that in astronomy, trigonometry and geometry, Indian efforts in Arabic and Persian are not inconsiderable, but in algebra it appears that no progress was made over the writings of Mohammad Musa Al-Khwarizmi, who had given the six quadratic algebraic equations in his text *Al-Jabr-wal-Muqabalah,* although Omar Khayyam had earlier dealt with a cubic equation and Ibn Al-Haitham had treated a liner indeterminate equation.

III. GEOMETRY

The origin of arithmetic can be traced back to the human need of counting, leading to the concept of integers or natural numbers. Algebra is an advanced stage of arithmetic where instead of known numbers, general quantities are taken as the basis, and the rules of operation here are not much different from those in arithmetic. Geometry, on the other hand, steps in where figures are involved. Figures are integral parts of houses, fields and the like. As far as we know, the earliest Indian civilization—that of the Sind valley, Mohanjodaro and Harappa—was very advanced; roads were planned, architecture was developed for construction of houses, etc. But we do not have any literature available at present to guide us as to the forms and the rudimentary rules involved in their planning.

It is also believed that geometry originated in rituals. It was conjectured by Seidenberg[1] that 'Greek geometry contained many aspects that can be explained on the assumption that it derives from rituals of the kind we find with the Indians. Whether Greek geometry derives from the Indian rituals or from a different system very much quite different, it is not essential to decide.'

The earliest indication of religious rituals leading to the origin of geometry in India have been found. According to Shukla:[2]

> Geometry originated in a very remote age in connection with the construction of the altars for Vedic sacrifices... according to the strict injunctions, sacrifices had to be made in an altar of prescribed shape and size. There were multitudes of altars... but the area of each had to be the same and equal to 4 sq. yards.... There were altars of the shape of falcon with straight or bent wings on a square and equilateral triangle and isosceles trapezium, a circle, a wheel (with or without spokes), a tortoise, a trough and other complete forms, all having the same area. Again, on the second and each subsequent

construction of an altar, it was necessary to increase its size by a specified amount.... Thus there arise problems of equivalent area and transformation of areas.

Sulba Sutra

The earliest literature regarding the construction of fire altars for sacrificial purposes is known as Sulba sutra. It has been conjectured that these date back from 800 to 500 BC. At present seven Sulba sutras are known, but Shukla[3] believes that 'many more such works existed in ancient time'.

The Sulba sutra contained quite a few theorems whose application was implicit in the construction of altars of different shapes and sizes. For example,[4] the diagonals of a rectangle bisect each other; they divide the rectangle into four parts, two and two (vertically opposite) of which are equal in all respects. Likewise:

- The diagonals of a rhombus bisect each other at right-angles.
- An isosceles triangle is divided into two equal halves by the line joining the vertex to the middle point of the base.
- The area of a square formed by joining the middle points of the sides of a square is half that of the original one.
- The diagonal of a rectangle produces both areas which its length and breadth produces separately.

Theorem of Baudhāyana or Pythagoras?

The last theorem attributed to Baudhāyana (*c.* 820 BC) is the same as the Pythagoras theorem—that is, in a right-angle triangle, the square of the hypotenuse is equal to the sum of the squares on the two sides. But, as Heath points out,[5] 'no really trust-worthy proof exists that it was actually discovered by Pythagoras'.

It was known that some earlier nations had knowledge of some particular cases, but Baudhāyana was possibly the first to enunciate the theorem in its general form. However, the proof of the above theorem as given by Baudhāyana had not yet been determined with certainty. Colebrooke[6] had conjectured that Baudhāyana's proof was given by Bhāskarācārya and did not occur in the West until 1693, when it was rediscovered in Europe by E. Wallis.

In any case, construction and necessary computation became a part of arithmetic (pāṭīgaṇita) and remarkable work was done; but on the whole, in India, geometry remained empirical. There were no definitions, no postulates, no axioms, no proofs of the theorems. As Sarasvati Amma[7] puts it, 'The aim was not to build up devices of geometry on a few axioms but to convince the intelligent student of the validity of the theorems.'

Even as late as the fifteenth century, a mathematician like Nīlakanṭha Somayaji[8] produced the authority of Dharmaśāstra texts, *Viṣṇu* and *Bhagvat Purāṇas, Mimāmsā* and *Vedānta Darśanas* for proving his mathematical assertions in the *Āryabhaṭṭīyabhāṣya.*

Algebraic solutions of Baudhāyana's principles took the form of the indeterminate algebraic equation $x^2 + y^2 = z^2$ and the solution was to be found even when one of the variables representing the base, altitude or a hypotenuse was given. Starting from Kātyāyana (*c.* 500 BC) integral or rational solutions were obtained in the medieval period. Bhāskara-II (1150) and Gaṇeśa (1554) also considered the equation.

Here is a particular case: when one side was given, the other two were determined by many mathematicians. For example, the perpendicular, the base, or the hypotenuse could be determined if a side is given to be 12. Bhāskara-II[9] obtained four right-angled triangles with sides (12, 35, 37), (12, 16, 20), (12, 9, 15) and (12, 5, 13).

The rationale of the first solution was given by Suryadasa[10] (1538) in modern notation. Starting with the rational right triangle $n^2 - 1, 2n, n^2 + 1$, he observed that if x, y and z be the corresponding sides of another right-angled triangle, then:

$$\frac{x}{n^2-1} = \frac{y}{2n} = \frac{z}{n^2+1} = k \text{ (say)}$$

Hence $x = \frac{k}{n^2-1}$, $y = 2nk$ and $z = k(n^2+1)$

Therefore, $x + z = 2kn^2 = ny$

If now we have $x = a$, then

$$k = \frac{a}{n^2-1}, \quad z = \frac{a(n^2-1)}{n^2+1} \text{ and } y = \frac{2na}{n^2-1}$$

Area of a triangle

The formula for the area of a triangle according to Sulba was: Area = 1/2 (base x altitude). However, according to Brahmagupta (628), if a, b and c are the three sides of the triangle, the area would be roughly equal to $\frac{1}{4}(a+b)c$ and the exact area would be $\sqrt{\{s(s-a)(s-b)(s-c)\}}$ where $s = (a+b+c)/2$ ....

Many mathematicians up to Bhāskara-II used both the formulae for calculating rough and exact areas, but Bhāskara-II used only the exact formula, which was supposed to have been given by Heron[11] of Alexandria. Formerly, formulae for determining the radius of the circle circumscribing a given triangle and also the circle inscribed in it were given (simple formula). Several mathematicians tried to obtain the formulae regarding quadrilaterals, but Āryabhaṭṭa-II[12] remarked:

> The mathematician who wishes to tell of the area or the altitude of a quadrilateral without knowing a diagonal, must be a fool or blunderer.

Brahmagupta (628) gave the formula:

$$\text{Area} = \sqrt{(s-a)(s-b)(s-c)(s-d)}$$
$$\text{where } 2s = a + b + c + d$$

This formula was represented by Śrīdhara (900), Mahāvīra (850) and Śrīpati (1039). None of these writers had expressly mentioned the limitation that it held true only for an inscribed figure. Still, this seemed to have been implied by them.

It appears that Bhāskara-II had the above principle in mind when he gave a warning that:[13]

> The diagonals of a quadrilateral (whose four sides are given) are uncertain. How can then the area be determined? The diagonals as calculated by previous teachers will be true only in the case of quadrilaterals (of a particular kind) contemplated by them but in case of others and with the same (four) sides, there can be various other pairs of diagonals and consequently the area also is manifold. In quadrilateral, when two opposite corners are so drawn as to bring the sides contiguous to them inwards, the diagonal joining them is shortened while the other two corners bulge outwards and consequently, the diagonal is lengthened. So it has been stated (just before) that with the same sides, there could be other pair of diagonals without specifying one of the altitude or diagonal, how then can one ask to find the other of them and also the area as these are truly indeterminate? The questioner who does not know the indeterminate nature of the quadrilateral must be a blunderer, still more so is he who answers such a problem.

The sides of the circumscribed and inscribed circles, the diagonals and areas have been laid down.

Squaring the Circle and Circling the Square

The problem dates back to the Ṛg Vedic time and Sulba sutra in connection with the transformation of circular altars preserving the area but changing the form from circular to square or square to circular. Since in that connection the ratio of the circumference and the diameter was the main problem, which was found to be 10 or $\frac{22}{7}$ or 3 + some fraction. Before the medieval period Āryabhaṭṭa-I (499) took $\pi = \frac{21600}{6876}$ which was worked out by Bhāskara-I (629) as $\frac{600}{191}$, and even during the medieval period by Gaṇeśa-II (1550) and Munīśvara (1656). However, the Greek value $\pi = \frac{22}{7}$ was introduced by Āryabhaṭṭa (499) in India in his work. Later on Bhāskara-II[14] implied it as a rough approximation suitable for practical purposes. Later, Nārāyaṇa Paṇḍita[15] (1426) used the value of circular shape having a given perimeter and suggested the formula:

> Divide the given perimeter into 710 parts with 113 of them as the radius, describe a circle and thus construct the circular temple.

This in fact was the same as the Chinese value $\frac{355}{113}$.

Later on, Śaṅkara Vāriyār[16] (*c.* 1500-60) found the value:

$$\pi = \frac{104348}{33215} = 3.14159265391$$

Putomana Somayaji (*c.* 1660-1740) used the value of n = 3.1415926536

Śaṅkaravarman (*c.* 1800-38) found the value of $\pi = 3.14159265358979324$ correct up to 17 places of decimal. It is interesting to note that Śaṅkara Vāriyār (1500-60) had expressed the value of π in the form of a slow convergent series two centuries earlier than Leibniz (1673) and DeLagney (1682).

Śaṅkaravarman[17] also expressed that the ratio of the circumference is a difference of two convergent infinite series.

$$\left(\sqrt{12}\ \frac{1}{9(2.1-1)} + \frac{1}{9^2(2.3-1)} + \frac{1}{9^3(2.5-1)} + \ldots\right) +$$

$$\left(\sqrt{\frac{12}{3}}\ \frac{1}{9(2.2-1)} + \frac{1}{9^2(2.4-1)} + \frac{1}{9^3(2.6-1)} + \ldots\right)$$

Measurement of Segment of a Circle

The formulae for the area of a segment of a circle were earlier given by Śrīdhara, Mahāvīra, Āryabhaṭṭa-II and Śrīpati (1039), but their formulae only determined approximate results. On the other hand, Bhāskara-II[18] (1150) wrote:

> Find the square-root of the product of the sum and difference of the diameter and chord; and subtract it from the diameter; half the remainder is the arrow (the perpendicular from the mid-point of the chord to the circumference of the circle), the diameter being diminished and then multiplied by the arrow twice the square-root and

the result is the chord. In a circle, the square of a semi-chord being divided and then increased by the arrow, the result is stated to be the diameter.

The formulae for volumes of various solids like cones, pyramids, prisms, and cylinders were enunciated by ancient Indian mathematicians. Many such solids were found in excavations of anthropological sites. However, no methodical forms were obtained by later writers. For example, Mahāvīra[19] (800) gave examples of excavation of various kinds which were inverted uses of truncated pyramids and square rectangular or equilateral triangular bases and truncated cones.

Āryabhaṭṭa-II gave the formula: 'Divide the sum of the area of face, base and that arising from sum of the dimensions of them by six, the quotient multiplied by the height will be the volume of an excavation such as a well and tank.' Śrīpati and Bhāskara-II adopted the same formula in their calculations.

Indian mathematicians up to the middle ages also laid down formulae for the surface and volume of a sphere, in which the ratio between the circumference and diameter (π) was used; but, although the value of π had been obtained to many places of decimal, even Bhāskara-II used the rough value of $\pi = \frac{22}{7}$.

It can be seen that central and west Asian mathematicians had accepted Greek geometry which was a deductive science and had come to be recognized as Euclidean; whereas geometry in India started transforming the shape of altars while retaining the area, but with post-sulba geometry, the emphasis turned to mensuration of rectilinear figures and volumes of a few solids. The first Indologist Abu Rehan Mohammad ibn Ahmad Al-Beruni (AD 973-1048) did make an attempt[20] to translate some works into Sanskrit from Arabic. He had great admiration for Indian mathematicians but felt that their geometry suffered from lack of vigour. He noted in his *Kitab al-Hind*[21] that 'Most of their books are in ślokas, in which I am now exercising myself, being occupied in composing for the Hindus a translation of books of Euclid, being simply guided by the desire of spreading science.' But the historians of Indian mathematics[22] only remarked that 'Al-Beruni's attempt did not succeed'.

In early days of Abbasid Khalifas (Al-Mansur, Al-Rashid, Al-Mamun), a number of copies of Euclidean text were procured from Byzantine, the main attraction being Aristotelian logic used in establishing principles. Heath[23] gave a list of thirty-one writers who had translated some or all of the thirteen books of Euclid or written commentaries based on these books. The earliest translation was made by Hajjaj bin Yusuf and it was again revised and improved by Thabit bin Qurra (AD 826-901). But the most important work in this area was *Tahrir Kitab Usul al-Handasah wal-Hisab al-mansub ila Uqlidis* (popularly known as *Tahrir Uqlidis*) by Nasir al-Din Muhammad bin Muhammad al-Tusi. *Tahrir Uqlidis* was among one of the most important sources by which Euclidean geometry was introduced in India, and scholars whose language was Arabic/Persian treated it as the main text. Apart from the commentaries and glosses on this Arabic recension written elsewhere, a large number of tracts were composed by Indians also. The earliest commentary written in India was *Sharh Tahrir-Usul al-Handasah-wal-Hisab* by Mir Muhammad Hashim bin Qasim al-Husaini in Arabic in Shah Jahan's time. A Persian translation was composed by Khair-ul-Lah Khan bin Lutf-ul-lah Khan (1731/32) and many authors like Barkat bin Abd al-Rahman Allahabadi, Hasan ibn Dildar Ali Nasirabadi, Mufti Ali Kabir Jaunpuri and Rukn al-Din Lakhnavi. As the original text was prescribed for students in madrasahs, many commentaries continued to be written. Rizvi[24] has found an important commentary entitled *Mukhtalif Shahrh Tahrir Uqlidis* at Nasirya Library of Lucknow, in which references from many authors were given, but the author's own name is not mentioned; only the date of its purchase (AD 1799) is noted.

Definitions

In earlier Sanskrit works of geometry, generally there was no particular emphasis on definitions of the technical terms, as the main purpose was construction of figures and mensuration, while the commentators on *Tahrir Uqlidis* did not restrict themselves to giving definitions as laid down in it. For example, Euclid defined a straight line[25] as 'a line which lies evenly with the points on itself'. Earlier Plato had defined a line as 'that of which the middle covers the ends'. The Indian commentator Mir Muhammad Hashim[26] said that 'a line is said to be straight if whatever point be supposed on it, each one of them will be opposite (Mutaqabil or face-to-face) to the remaining points.' (Mutaqabil here meant the no point should be up and down in respect of others in one direction).

Similarly, Euclid[27] defined surface as 'that which has length and breadth only'. The extremities of a surface were a line and a plane surface was 'a surface which lies evenly on the straight line on itself'. According to Mir Muhammad Hashim,[28] 'All the points taken on a surface should be opposite to each other.' The meaning of opposite here was the same as stated earlier. He remarked that sometimes it so happens that a surface instead of terminating in a line tilts at a point, for example, in a cone, which terminates at one end in a point and the other in a circle.

A plane angle was defined by Euclid[29] as 'the inclination to one another of two lines in a plane which meet one another and do not lie in a straight line.' There was a conceptual controversy about angles being a quantity (Maqala-e-kam), a quality (Maqula-e-Kaif) or a state (Waza). Some like Mir Muhammad Hashim put it in the category of magnitude and argued that an angle could be partitioned similar to a surface. He gave an elaborate classification of angles as follows:

(a) convex-convex;
(b) concave-concave;
(c) convex-concave;
(d) line-convex;
(e) line-concave.

Here, too, 'convex-convex' meant an angle bounded by two circular arcs with convexity outwards; 'line-convex' meant an angle bounded by a straight line and an arc with convexity outwards; and so on. A text entitled *Al-Hāwiyah fi Tahqīq-i-Zawiyah*[30] had a detailed discussion about the meaning of angle from the geometric point of view. As the latest authors quoted in the tract—Mulla Mahmud Jaunpuri, Baqir Damad and Sadr al-Din belonged to the seventeenth century, it was conjectured that the author was an Indian who flourished in the seventeenth century. The Arabic manuscript is available at the Bankipur Library, Patna.

A figure was defined as one which was enclosed by one boundary or many boundaries. Some geometers included line also in a figure. Mir Muhamad Hashim had the same view. Indian mathematicians writing in Arabic or Persian also considered the following non-rectilinear figures:[31]

1. *Turnip-like (Shaljami) surface* enclosed by two arcs of different convexity of two equal circles which are greater than the semicircle. The line joining the intersection of the two arcs is the minor diameter and the line bisecting each other is the major diameter.
2. *Crescent-like surface* is the one enclosed by two arcs—one from the concave side, the other from the convex side. Both the arcs are smaller than the semicircle.
3. *Horse-shoe surface* is like the crescent, but each arc is greater than the semicircle.

Earlier, Indian mathematicians like Śrīdhara, Mahāvīra, Āryabhaṭṭa-II and Bhāskara-II treated mensuration of plane figures, like non-rectilinear figures, as the shape of a barley corn (yava), drum (muraja, mṛdaṅga), elephant's tusk (gajadanta), crescent moon (bālendu), felloe (nemi), thunder-bolt (vajra), etc. The formulae described for most of them were only roughly approximate.

Ellipse

Ellipse[32] was known as early as about 400 BC, but no formula was found in any text before *Ganita-sāra-saṁgraha* of Mahāvīra (850), wherein only rough approximate results were given. According to him, in modern terminology, if 2a and 2b be the longer and shorter diameter, respectively, then:

$$\text{Circumference (Gross)} = 2\ (2a + b)$$

$$\text{Circumference (Neat)} = \sqrt{16a^2 + 24b^2}$$

$$\text{Area (Gross)} = b\ (2a + b) \text{ and}$$

$$\text{Area (Neat)} = \frac{1}{2} b \sqrt{16a^2 + 24b^2}$$

But, according to mathematicians writing in Persian or Arabic, an elliptic[33] figure 'is a surface which has a single line as the boundary and it has two diameters—one is major and the other minor; and they intersect at right angles; and on two sides of intersection on the major diameter two points can be found at equal distance such that from these two points two straight lines are drawn; which meet at a point on the boundary and the sum of these two lines is always equal to the major diameter; and the boundary of the elliptic surface is called elliptical line.'

Some theorems about the properties of ellipse, including the method of construction of ellipse, were given in an early nineteenth century compendium[34] entitled *Jame-i-Bahadurkhani* by Ghulam Husain Jaunpuri.

Parallel Postulate

The parallel postulate is known as Euclid's Fifth Postulate, whose statement runs as follows:[35]

> If a straight line falling on two straight lines makes the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right-angles.

There was difference of opinion[36] since antiquity about whether this so-called parallel postulate should be treated as a postulate, an axiom or a proposition. But a majority of the great geometers considered that this postulate was capable of proof and attempts to prove it were made by Ptolemy and Proclus. Even Nasir al-Din Tusi considered this proposition as a problem. In India, Mir Mohammad Hashim bin Qasim Ali Husaini (1561-1652) writing in his commentary on *Tehrir-i-Uqlidis* entitled *Sharh Tahrir-i-Uqlidis* remarked[37] that this postulate was not self evident like the others and may be proved by paying a little attention towards it.

Geometry of Solids

The Greek classic *Spherics* of Theodosius was available in at least three or four Arabic translations but *Tahrir Ukar Thaudhusiyus* was more popular among students. In India, a Persian translation[38] entitled *Raid al Nufus Tarjumah-i-Ukar-i-Thaudhusiyus* by Ghulam Husain Jaunpuri, appeared in the late eighteenth century.

Archimedes's treatise[39] on spherics and cylinders was available to students in Arabic as *Kitab al-Kurah wal Ustuwanah.* Originally the translation was made by Thabit bin Qurrah and Ishaq bin Husain, and Nasir al-Din Tusi added further comments. The other text on conics by Apollonius was also translated into Arabic by Nasir al-Din Tusi as *Ar-risalat al-qita* *fi ilm handasah* in AD 1260. On this topic *Jame-i-Bahadurkhani* contained fifty-three theorems of Theodosius, five of Archimedes, and two of Appolonius in Persian, which were studied by students of higher classes in Persian/Arabic madrasahs.

Thus, the commentaries in Persian or Arabic by Indians were not merely mechanical translations of the text but also contained new ideas in the form of definitions, explanations and proofs.

Al-Beruni's Dream Comes True

Al-Beruni had attempted to introduce Euclid's *Elements* but it took more than four hundred years to trickle into the country. Farishta[40] claimed that 'Firoze Shah Bahmani (AD 1397-1422) used to hear lectures on geometry and other subjects. A son of Daud Shah was very fond of *Tahrir-i-Uqlidis* and used to teach it regularly to his students. In his *Ain-i-Akbari*, Abul Fazl (AD 1590) has shown thorough acquaintance with the work while Akbar included it into a course of study for schoolboys.'

An eminent scholar of Akbar's court, Fath-ul-lah Shirazi, used to teach Euclidean geometry regularly. By the seventeenth century, Euclidean geometry began to be introduced through Sanskrit.[41] In AD 1658 Kamalākara, the court astronomer of Emperor Jehangir, wrote a voluminous treatise on astronomy entitled *Siddhānta-Tattva-Viveka*. Certain passages in this work could be easily recognized to have been adapted from Euclid's *Elements*. The first complete translation of the work in Sanskrit was made in AD 1727 under the title *Rekhāgaṇita* (Mathematics of Line) by Samrata Jagannatha, by the order of his patron, King Jayasimha of Jaipur. Another Sanskrit version is known as the *Siddhānta Chūḍāmaṇi*, but its author is still unknown.

Contrary to the earlier mathematicians who wrote in Sanskrit, these writers gave definitions of the terms used. For example, Jagannatha[42] defined a point as something that could not be divided. According to him, a line was something that is divisible in length but is without breadth. A straight line was supposed to be such that the points taken on it get covered and look like a single point.

During the early epoch of scientific activity in central and west Asia, many Arabic versions appeared under the title *Al-Ukar*.[43] It is interesting to note that the most important translations were those of Thabit bin Qurra, Qusta bin Luqa and Nasir al-Din Tusi, who had also composed their own recensions of Euclid's *Elements*. When and how any of these works reached India cannot be said with certainty. However, the first Indian translation entitled *Ukarakhyagrantha* composed by Nayansukha Opadhyaya under orders of the celebrated Jayasimha appeared in AD 1730. Compilers of a bibliography of Sanskrit works on astronomy and mathematics observed that:[44]

> The work appears from the figures given in illustration to be a treatise on spherical geometry. Originally a Greek work, the book was later translated into Arabic by several people. Kustaviviluk Balbhui (Qusta bin Luqa?) translated it up to the fifth figures of the third chapter, at the request of Abul Abbas Ahmad and the remaining portion was translated by others, whose names are not given. Savita Vimkusais (Thabit bin Qurra?) corrected the work and Nasir made a commentary on it. Taking the help of one Abid, Nayansukha translated it from the Arabic version into Sanskrit in AD 1730.

This 'Abid' was most probably an astronomer connected with the Delhi observatory during Muhammad Shah's reign.

Many commentaries and notes on Euclidean geometry were written by Indians in Persian or Arabic. However, no such commentaries seem to have been written in Sanskrit, although Euclidean geometry was introduced into Sanskrit through English, when the new system of education was being established. In 1873, at the instance of A.F. Trover,[45] the then secretary of Calcutta Sanskrit College, five chapters of Hutton's *Euclidean Geometry* were rendered into Sanskrit by Yogadhyan Misra under the title *Kṣetra-tattva-pradīpikā.*

A Method For Evaluation of π

The ratio of circumference of a circle with its diameter had been a favourite subject of study for the Indian mathematicians starting from the early Jain writers (500-300 BC to Āryabhaṭṭa (AD 476), Brahmagupta (AD 628), Lalla (AD 749), Śrīdhara (AD 850), Bhaṭṭopāla (AD 960), and Bhāskara-II (AD 1150). These writers found the *sthūl* value of the $\prod$ while Jyesthadeva[46] gave a geometrical method of finally arriving at:

$$\pi = \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \dots\right)$$

However, others do not specify the method. According to Cajori,[47] a commentator on *Līlāvati,* these values (Āryabhaṭṭa's and Bhāskara's) were calculated starting with a regular inscribed hexagon and applying repeatedly the formula:

$$AD = \sqrt{2 - \sqrt{4 - AB^2}}$$

where AB was the side of the given polygon and AD that of the one with double the number of sides. In this way the perimeter of the inscribed polygons of 12, 24, 48, 96, 192, 384 sides were obtained.

The polygon[48] of 384 sides gave good approximate value correct to four decimal places. But the formula failed to give more accurate value, because at each step of the doubling operation the value computed was in excess of what should have come in increasing order.

Ghulam Husain adopted a new technique of computation. He directly took an arc of a very small part of circumference (e.g. one minute) and described an equilateral and equiangular polygon whose sides were 21600 (i.e. the number of minutes in the entire circumference). Taking the mean of the perimeters of 21600 sided, inscribed and circumscribed polygon, after some calculations, he arrived at the final result:

$$\pi = 3 + 8/(60) + 29/(3600) + 43/(216000) + 30/(12960000) + 112/(777600000)$$

in sexagesimal fractions, or in decimal fractions 3.141590.

The above discussion indicates how in India an impetus was given to activities in mathematical sciences through Arabic and Persian literature. If and when[50] a proper study is made, it will give a lie to the canard spread by G.K. Kaye that the seven centuries from the thirteenth to the nineteenth were a dark period in India as far as mathematical sciences were concerned. Those who believe in this imperialist propaganda forget that not very distinguishing ideas may have come through Arabic and Persian, but at least much of the earlier wisdom was preserved. In the works of Rangachari:[51]

> This amounts to setting aside C.M. Wish's findings as elaborated and up-dated by Prof. C.T. Rajagopal and his collaborators (to the satisfaction of leading international mathematical historians like J.E. Hofmann, A.P. Yousckhevitch and D.T. Whiteside) that the seeds of mathematical analysis were sown in India (especially in Kerala) some two centuries ahead of Newton and Leibniz.

One need not be reminded that the all time greats Bhāskara-II, Nārāyaṇa Paṇḍita, Śaṅkaravāriyār, Śaṅkaravarman, Ghulam Husain, Mir Hashim and the like, were born, lived, worked, contributed and enriched mathematical sciences just during the so-called 'dark period'.

IV. TRIGONOMETRY

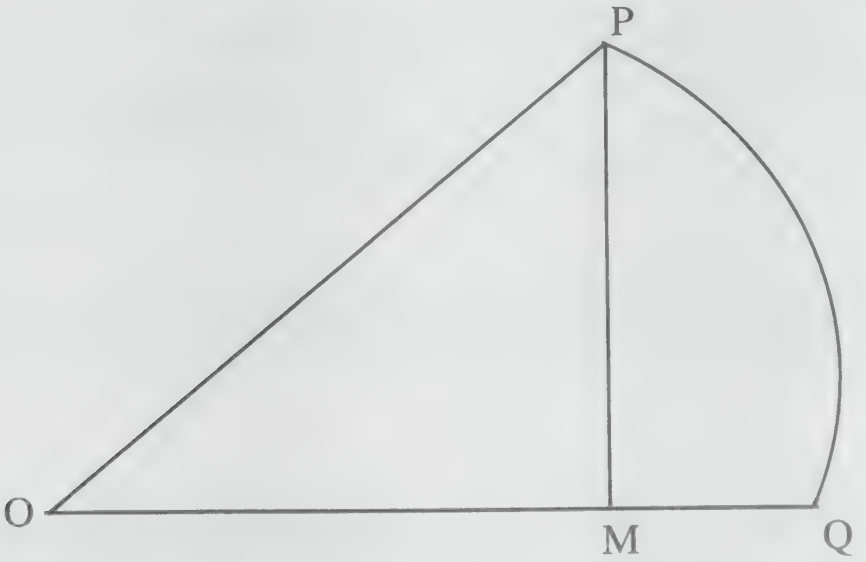
Trigonometry is an important mathematical tool in astronomy as it helps determine the position of stars and celestial bodies. Amongst the earliest civilizations like Egypt, Babylon and Asia Minor, astronomical studies and observations had developed to a fairly high degree, which was subsequently systematized in Greece.[1] For some two and a half centuries, Greek mathematicians had studied the relationship between lines and circles and had applied these to a variety of astronomical problems, but no systematic trigonometry had resulted. Then, presumably during the second half of the second century BC the first trigonometry table appeared which was apparently compiled by the astronomer Hipparchus of Nicosia (180-125 BC), who thus earned the right to be known as the father of trigonometry.

A circle is geometrically taken to be of 360 degrees, possibly based on the duration of a year and return of the same season after a complete revolution of the sun. It is not known[2] 'just when the systematic use of 360° circle came into mathematics but it seems to be due largely to Hipparchus in connection with his table of chords. Just how Hipparchus made his table is not known, for his work is not extant. It is likely that his methods were similar to those of Ptolemy.' Ptolemy's *Almagest*[3] is 'presumed to be heavily indebted for its method to Hipparchus's *Chords in a Circle*, but the extent of indebtedness cannot be reliably assessed.' As *Almagest* continued to be a valuable resource book on astronomy in Europe and west Asia, the concomitant trigonometry also continued to be based on Hipparchus's method of chords.

Indian trigonometry, on the other hand was based on arcs of a circle. Although Indian astronomy was as old as the Vedas, yet no trigonometrical tables of that period are known to exist. The earliest work on astronomy which contained a method of computing trigonometrical functions was the *Sūrya Siddhānta* (*c.* AD 300) in which, instead of Hipparchus' method based on chords, the arc of a circle of certain radius was laid down.

Trigonometrical Functions

The three functions *jya, kotijya* (or *kojya*) and *utkramajya* form the basis of Indian trigonometry. If PQ be an arc of a circle with centre at O, its *jya* = PM; *kotijya* = OM; and *utkramajya* = OQ – OM = AM. Hence their relation with modern trigonometrical function would be:[4] *jya* PQ = R sin A; *kotijya* PQ = R cos A; and *utkramajya* PQ = R – R cos A where R is the radius of the circle and A the angle subtended. It is to be noted that these are the functions of the arc PQ and not of the angle A.



The Sanskrit word *jya* means a bowstring; *kotijya* is 'the curved end of a bow'; and *utkramajya* means reversed *jya*.

Quadrants

Earlier mathematicians used the division of a circle into four quadrants, but a clear explanation was given by Bhāskara-II (1150):[5]

> On a plane surface describe a circle of any specific radius with a pair of compasses. Mark on its circumference 360 degrees. Draw the east-to-west and north-to-south lines through its centre. These lines will divide the circle into quadrants which should be taken into consideration in the leftwise manner (*savya-krama* or anticlockwise) proceeding from the east-point (*praci*); they should be called odd and even (quadrants), respectively.

Bhāskara-II further elaborates:

> In the first quadrant mark a point on the circumference of the circle at any optional distance from the east point.... As the point gradually moves forward in the same way (i.e. anticlockwise) *jya* increases and *kotijya* decreases. When the point arrives at the end of the quadrant, the *kotijya* vanishes and *jya* is equal to the radius. Then in the second quadrant, the *kotijya* increases; at the end of that quadrant the *kotijya* is maximum (irrespective of sign) and the *jya* vanishes.

Earlier in *Sūrya Siddhānta* it had been stated[7] that 'in odd quadrants, the arc passed over gives the *jya*, while the arc to be passed over gives the *kotijya*; and in the even quadrants the arc to be passed over gives the *jya* and that passed over gives *kotijya*'.

Relation Between Complementary Functions

Indian mathematicians like Bhāskara-I, Lalla, Brahmagupta, Manjula and Varāhmihira had already obtained such results even before the medieval period. Later mathematicians like Śrīpati (1034) believed[8] that 'The square of radius diminished by the square of the *jya*; the square-root of the remainder will be *kotijya*. Again the square-root of the square of the radius minus the square of *kotijya* will be the *jya*. The radius minus *utkramajya* of the complement of an arc is equal to *jya* of the arc, and minus the *utkramajya* of the arc becomes the *jya* of the other (i.e. the complement).' Similar formulae have been laid down by Bhāskara-II and Kamalākara which, in modern notations, are expressed as:

$$\sqrt{1-\sin^2 A} = \cos A, \sqrt{1-\cos^2 A} = \sin A.$$

Trigonometric Formulas

There were many formulae known by Indian mathematicians, which were applied for the solution of astronomical problems; where the language of *jya* and *kotijya* of an arc was used in place of the corresponding sine and cosine of an angle subtended at the centre of a circle of unit radius. For example, in modern notation:

1. $\sin^2 A + \cos^2 A = 1$
2. $4 \sin^2 A = \sin^2 2A + \text{versin}^2 2A$.

These formulae were stated first[9] by Varāhamihra (505) and were possibly known earlier to Āryabhaṭṭa-I (499) and later expressed by Śrīpati (1039), Bhāskara-II (1150) and Parameśvara (1430).

3. $\sin(45° - A) = \sqrt{\frac{1}{2}(\cos A - \sin A)^2}$

In the words of Bhāskara-II, 'The square of the difference between the *jya* and *kotijya* of an arc is halved; the square-root of the result is equal to the *jya* of half the difference between that arc and its complement.'

Kamalakara writes that 'The *jya* of half the difference between an arc and its complement is equal to the square-root of half the square of the difference of *jya* of the arc and of its complement.'

4. Bhāskara-II's addition theorem stated:[10]

> The *jyas* of any two arcs of a circle are reciprocally multiplied by their *kotijyas*; the products are then divided by the radius; the sum of the quotients is equal to the *jya* of the sum of two arcs and their difference is the *jya* of difference of the arcs.

This in modern symbols could be expressed as:

$\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B$.

The complement to Bhāskara's theorem was established by Kamalākara[11] as:

> The product of the *kotijyas* and *jyas* of two arcs of a circle are divided by its radius, the difference and sum of the (quotients) are equal to the *kotijya* of the sum and difference (respectively) of the two arcs.

According to Shukla[12] 'Though we do not find this *kotijya* theorem in the printed editions of the works of Bhāskara-II, we are quite sure that it was known to him. For it has been attributed to him by his most relentless critic Kamalākara as well as by his commentator Munīśvara.'

Kamalākara observed that the above theorems have been proved by algebraic as well as geometric methods, and he himself advanced two geometric proofs which were given in *Siddhānta-Tattva-Viveka.*

Derivation for Multiple Arcs

As a corollary of the general addition and subtraction theorems, Bhāskara-II indicated how to derive the function of multiple arcs. He observed:[13]

> Take the case of the combination of functions of equal arcs; by combining the functions of any arc with those of itself, we get the functions of twice that arc; by combining the functions of twice the arc with those of twice the arc we get functions of four times that arc; and so on. Next take the case of combination of functions of unequal arcs; on combining the functions of twice the arc with those of thrice that arc, by addition theorem we get functions of five times that arc but by the subtraction theorem we get the functions of one time that arc; and so on.

These theorems have been expressly stated by Kamalākara (1658), and by successive application of addition theorem establishes the following formulae[14] for the arc:

1. $\textit{jya}\ 3C = \{3R^2\ \textit{jya}\ C - 4(\textit{jya}\ C)^3\}/R^2$
2. $\textit{kotijya}\ 3C = \{(14\ (\textit{kotijya}\ C)^3 - 3\ R^2\ \textit{kotijya}\ C)\}/R^2$
3. $\textit{jya}\ 4C = 4\ \{(\textit{kotijya}\ C)^2\ \textit{jya}\ C - (\textit{jya}\ C)^2\ \textit{kotijya}\ C)\}/R^3$
4. $\textit{kotijya}\ 4C = \{(\textit{kotijya}\ C)^4 - 6\ (\textit{kotijya}\ C)^2\ (\textit{jya}\ C)^2 + (\textit{jya}\ C)\}^4/R^3$
5. $\textit{jya}\ 5C = \{(\textit{jya}\ C)^5 - 10\ (\textit{jya}\ C)^3\ (\textit{kotijya}\ C)^2 + 5\ \textit{jya}\ C\ (\textit{kotijya}\ C)\}^4/R^4$
6. $\textit{kotijya}\ 5C = \{(\textit{kotijya}\ C)^5 - 10\ (\textit{kotijya}\ C)^3\ \textit{jya}\ C)^2 + 5\ \textit{kotijya}\ C\ (\textit{jya}\ C)\}^4/R^4$

The same theorems have been applied for evaluating *jyas* of sub-multiples as well.

Trigonometric Tables

The earliest tables of the *jya* relationship that have survived are those in the *Siddhāntas* and the *Āryabhaṭṭīya.* Let us have a look at these tables:

1. *Sūrya Siddhānta*[15] had a table of *jyas* and *utkramajyas* for every arc of 3°45' of a circle of radius 3438'. The method of computation was indicated to be as follows:

> The eighth part of the number of minutes in a sign (i.e. 225') is the first *jya.* It is divided by itself and then diminished by the quotient; the remainder added with the first *jya* gives the second *jya.*
>
> (Any) *jya* is divided by the first *jya* and then diminished by the quotient. The remainder added to the difference and the preceding *jya* will give the next *jya.* Thus can be obtained 24 *jyas.*

According to Shukla,[16] this procedure had an important geometrical foundation. If there were three arcs of a circle on arithmetical progression, the sum of two extreme arcs would be the *jya* of the middle arc as the *jya* of twice the common difference would be the *jya* of that difference.

2. *Āryabhaṭṭīya* has given two methods, containing the difference between the successive *jyas* for arcs of 3°45' of a circle of radius 3438'. His first method is similar to that of Varāhamihira (587). The other method of Āryabhaṭṭa-I (499) is practically the same as given in *Sūrya Siddhānta.*

3. Varahamihra's (587) table contains the *jyas* for every 5°45' and successive differences of the tabular *jyas* for a circle of the radius 60'.

4. Lalla gives a table of *jyas* and *utkramajyas* for a circle of the radius 3438' using the method of Āryabhaṭṭa-I and *Sūrya Siddhānta.*

5. Brahmagupta (628) took a radius 3270' and gave two methods of computation: (a) mathematical and (b) graphic. The graphic method[17] consisted of starting from the joint of two quadrants to mark off successively (in either direction) portions of arcs equivalent to the eight parts of a sine (i.e. 3 3/4°). The two and two of these marks were then joined by threads. Half of the lengths of these threads represented the *jyas.*

6. Āryabhaṭṭa-II (950) gave the same table as that given in *Sūrya Siddhānta*, but applied the formula

$$jya\,\frac{1}{2}\,(90^\circ \pm C) = \sqrt{\frac{1}{2}(R^2 \pm R\; jya\; C)}$$

beginning with the known values of *jya* 30° and *jya* 45°.

7. Śrīpati (1039) followed both the mathematical and graphical methods of Brahmagupta but took the radius as 3415'.

8. Bhāskara-II (1150) presented many[18] methods for computing *jyas* and *utkramajyas* and their differences for every 3°45' of a circle whose radius was 3438'. While his first method was practically the same as Brahmagupta's graphic method, the second method was similar to Brahmagupta's theoretical method. Another method was based on the application of the formulae:[19]

$$jya\,\frac{1}{2}\,(A - B) = \sqrt{\frac{1}{2}\left\{(jya\,A - jya\,B)^2 + (kotijya\,A - kotijya\,B)^2\right\}}$$

$$jya\,(45^\circ - A) = \frac{1}{2}\,(kotijya\,A - jya\,A)^2$$

The above formulae were helpful in evaluating *jyas* and *kotijyas* if one or two *jyas* or *kotijyas* were known.

Most of the trigonometrical tables were based on the circle of radius 3438'. According to Boyer, in the earliest tables:[20]

> the sines of angles up to 90° are given for twenty-four equal intervals of $3\frac{3^\circ}{4}$ each. In order to express arc length and sine length in terms of the same unit, the radius was

taken as 3438' and the circumference as 360.00 = 21600'. For the sine of $3\frac{3^\circ}{4}$ the *Siddhāntas* and the *Āryabhaṭṭīya* took the number of units in the arc—that is, $60 \times 3\frac{3^\circ}{4}$ or 225. In modern language, the sine of a small angle is very nearly equal to the radian measure of the angle. For further items one easily deduces that sin 7.5° = 449, sin 11.25° = 671, sin 15° = 890, and so on up to sin 90° = 3438—that is, the values listed in the tables in the *Siddhānta* and the *Āryabhaṭṭīya*.... If we divide the items in the tables by 3438, the results are found to be in close agreement with the corresponding values in modern trigonometric tables.

Tangent and Secant

The trigonometrical tables gave *jyas* and *kotijyas* of different angles but did not calculate tangents and secants. In fact, in spherical trigonometry they were not recognized at all. *Sūrya Siddhānta* did give a rule for calculating the equinoctial midday shadow of the gnomon at a station. Sometimes[21] attempts were made to attribute the functions of tangent, cotangent, secant and cosecant to specific times and even to specific intervals. In India and Arabia there had been a general theory of shadow lengths as related to a unit length of gnomon for varying lengths of the staff or the gnomon used, although a hand-span or a man's height was frequently adopted. The horizontal shadow for a vertical gnomon of a given length was what we call the cotangent of the angle of elevation of the sun. The 'reverse shadow' (i.e. the shadow cast on a vertical wall by a stick or gnomon projecting horizontally from the wall) was what we know as the tangent.

From Jya to Sine

Indian trigonometry took the same route to Europe as did the Indian numerals. During the ninth century (AH) a number of Indian astronomical works were translated[22] into Arabic. *Brahmasphuṭa Siddhānta* was the first among them to be translated into Arabic with the help of an Indian pandit. He had two disciples—Ibrahim Fazari and Yaqub ibne-Tariq. They rendered the text in their own style. The translation was called *Sindhind*. Many writers worked on *Sindhind* and added their own contributions to it.

The principle of *Sindhind*[23] 'reached Spain in the fourth century AH (tenth AD). Muslema ibne-Ahmad Majriti (of Madrid, d. 398 AH/AD 1007) summarized Khwarizmi's *Zij-i-Sindhind Saqhir (Almanac of Siddhānta, abridged)*... and through Arabs of Spain, this Siddhānta reached the Jews and then Europe. Accordingly a Jewish scholar Abraham-bin-Ezra (1090-1167) compiled his Hebrew *Zij* based on some principles of *Siddhānta*.'

It was further noted that[24] 'a technical term which is still used in Arabic mathematics and trigonometry is *jaib*, which is mistakenly taken as the Arabic word *jaib* meaning breast collar', although it was actually the Sanskrit word *jya* or *jiva* arabicized. It was from this word that *jaib-al-tamam* and other terms followed. Thus, after pruning these terms appeared in Arabic mould, so much so that to date no one can suspect them to be non-Arabic.

In Europe[25] 'the Romans had never displayed much interest in Greek trigonometry, relatively useful and elementary though it was; yet Latin scholars of the twelfth century devoured Arabic trigonometry as it appeared in astronomical works. It was Robert Chester's translation (1150) from Arabic that resulted in our word "sine". The Hindus had given the name *jiva* (*jya*) and the Arabs had taken this over as *jiba* (or *jaib*). In Arabic language *jaib* also means "bay" or "inlet". When he came to translate he seems to have confused *jiba* and *jaib* and used the word *sinus*, the Latin word for bay or inlet, and gradually in other European tongues it became *sine*.'

Boyer observed that[26] 'as in numeration there was competition between systems of Greek and Indian origin, so also in astronomical calculations there were at first in Arabic two types of trigonometry—the Greek as found in the *Almagest*, and the Hindu table of sines as derived through the *Sindhind*. Here too the conflict resulted in triumph for the Hindu aspect, and most Arabic trigonometry was built on the sine function. It was in fact, again through the Arabs, rather than directly from the Hindus, that this trigonometry of the sine reached Europe.'

It can be mentioned here that back home in India, sine trigonometry based on *Sindhind* and subsequent texts based on it were for a long time in use in Arabic- and Persian-medium schools of learning. An Indian mathematician of the early nineteenth century, Ghulam Husain Jaunpuri in his compendium *Jame-i-Bahadurkhani* made this very clear:[27] 'One should know that the ancients, Hipparchus and Ptolemy, etc., have based the operation of astronomy and astronomical tables on calculation of chords; but *mutakhkhirin* (later writers) like Abu-Raihan Beruni, Khwaja Nasir al-Din Tusi, Ghyas-al-Din Jamshed, etc., till this day have based these calculations on sines, because computation based on sines is clearer and more incontrovertible than chord-based computation.'

Feed-back

Sine-based trigonometry returned to India many centuries later in the garb of Arabic or Persian, or retranslation into Sanskrit:[28] 'In 1370, Mahendra Suri, the court astronomer of Firoze Tughlaq introduced into Sanskrit some astronomical and trigonometrical principles that were current in central Asia. His *Yantraraj* is based upon Persian and Arabic sources. A disciple of his, Malyendra Suri, wrote a commentary in AD 1378 and another Sanskrit commentary was written 464 years later by Sudhakara Dvivedin.'

It was noted[29] that one of the main jobs of astronomers was preparation of *Zij* (table). It appears that at least 86 *Zijes* in Arabic and Persian were known to Indian astronomers during Akbar's reign. In fact, many emperors of Delhi and rulers of provincial kingdoms during the medieval period got such *Zijes* prepared by their court astronomers. To mention a few, *Zij-i-Nasiri, Zij-i-Rahimi, Zij-i-Shahjahani* were composed under the patronage of Iltutmish, Akbar and Shah Jahan, respectively. Ulugh Beg's *Zij* which remained for a long time an important source of astronomical computation was translated into Sanskrit under the supervision of Akbar's scientist-minister Fathullah Shirazi with the help of Abul Fazl. *Tārā Sāriṇi* is in fact a Sanskrit translation of *Zij-i-Ulugh Begi* prepared by Kewalarama Srimali, the Jyotis Rai of Sawai Jai Singh. Besides the *Zij-i-Shahjahani*, there is a manuscript entitled *Zij-i-Nityanandi Shahjahani* in the palace museum at Jaipur, prepared in Sanskrit by Nityanand in AD 1727. Jai Singh's *Zij-i-Muhammadshahi* comes as a landmark and so is *Zij-i-Nizami* which is a result of a close study of a number of astronomical classics. Trigonometric tables were usually an integral part of the *Zijes.*

One of the important problems in trigonometry was of finding the *jya* of a trisected arc. A good deal of work had been done by the Ulugh Beg school of Samarqand. The first Indian mathematician to work on this was Munīśvara (1150). In his commentary entitled *Mariec* (1635) based on Bhāskara-II's *Jyotpaṭṭī*, he gave a method of solution by setting up a cubic equation whose solution could be found by iteration. As an illustration, taking the entire arc of the first quadrant, he showed that *jya* 30°= R/2; and he admitted[30] that 'the method described by me here for *jya* of a trisected part was not given by the ancients', and in the end mentioned the name of Mirza Ulugh Beg and his work in this connection.

Later Kamalākara (1658) gave a method by setting up the equation:

$$jya\,\frac{A}{3} = \frac{1}{3}\,jya\,A + \frac{4}{81}\,R^2\,(jya\,A)^3$$

and suggested that this (rough) value of *jya* $\frac{A}{3}$ be used in place of $\frac{1}{3}$ *jya* A in the second term on the R.H.S. of the equation to get better value of *jya* $\frac{A}{3}$, and so on. Thus,[31] 'Kamalākara's method is the same as given by Munīśvara. However, Kamalākara's derivation as given in his own accompanying commentary, is simple, straight-forward, and truly trigonometrical. It is based on the identity:

$$R^2\ jya\ A = 3R^2\ jya\frac{A}{3} - 4\left(jya\frac{A}{3}\right)^3$$'

Kamalākara further added:[32] 'In the past, Sri Mirza Ullugh Beg also gave his own computation of the *jya* of one-third part by the method of (drawing) diagram inscribed in a circle.'

Jame-i-Bahadurkhani

Ghulam Husain Jaunpuri's compendium has been called the Encyclopaedia of Mathematical Sciences. Even a cursory glance at it shows the state of mathematical and allied sciences current in India during the last stages of medieval period through the Persian medium. In the 720 lithographed pages written during 1832-33, *Jame-i- Bahadurkhani* covers geometry, optics, arithmetic, trigonometry, astronomy, and preparation of *Zij*. The chapter[30] on trigonometry comprises an introduction and seven sub-chapters dealing with the magnitude of chords and sines, tangents and their exhaustive tables in sexagecimal system (accurately up to the fourth sub-divisions), division of circles, magnitude of the sine and angles of plane and spherical triangles and computation of elevations, breadth, etc. The trigonometric tables cover seventy-one pages giving sines (*jaib*) and their differences, besides tangents (*Zill-e-Ma'kus*) and their difference. Basically he followed the method laid down in *Siddhāntas* for computing *jaib* (*jyas*).

For verification, Rizvi considered chord length of 20° angle which was computed by Ghulam Husain[34] after solving the equation $x^3 + 1 = 3x$ from trisecting an arc which subtended an angle of 60° in the centre of the circle of radius 60. If the radius was 1 then $x = 20^{I}\,50^{II}\,16^{III}\,0^{IV}\,45^{V}$ (in sexagesimal notation) = 0.3472963529. Therefore, $\sin 10° = \frac{1}{2}$ (0.3472963529) = 0.1736481763.

which is correct up to eight places of decimal and is less than the actual value by the fraction of 6×10^{-10}; but this lesser quantity is approximately six part out of one thousand million.

It would be worthwhile to render this compendium into English or Hindi as it shows the level of mathematics written in Persian during that period in India.

V. MATHEMATICAL GAMES

The story goes that a mathematician wrote a novel and someone, being surprised, broke the news to Hilbert, but Hilbert laughed and said, 'In writing a novel, you need imagination and the man had imagination, only sufficient enough to write a novel, but he had insufficient imagination for becoming a good mathematician.' Mathematical games which provide entertainment require a lot of imagination. Incidentally, two of the most popular indoor games, i.e. *shatranj* (chess) and *chausar* or *nard* (draughts), are the products of Indian mathematical minds.

Representation of Philosophy

The best account of the origins of these games was written by the Arab historian Yaqubi.[1] According to him, 'These are not fun games only but are based on the delicate problems of mathematics and philosophy'. Explaining these problems, he then said that 'The board in fact represent the ups and downs of life. The square represent celestial mansions. On the board of *nard* (draughts) 36 days, 24 hours of a day, a day of 12 hours and a night of 12 hours are all represented. The basis of *shatranj* (chess) is 64 squares, and 32, 16, 8 and then 4.' But besides, these mathematical tricks, very little consideration was given to the fact that the two games were also the explanations of two religious or philosophical schools of thoughts in India. *Nard* (draughts) represented the philosophical dictum that man is a helpless creature before fate and that it was only the wish of heaven and the stars that forced him to do whatever he determined to do. In other words, in this world no step could be taken by man's own free will. There was some one else who forced him into takeing each step.

On the contrary, *shatranj* (chess) represented the fact that everything that happened in this world resulted from man's personal efforts. Victory or defeat, success or failure, depended on his heart, brain, understanding, and relentless effort. In other words, these two games were the practical designs of the insoluble problems of the world. Yaqubi writes that a paṇdit presented a rājā with a *nard* (draughts) board that he had created wherein he preached the principle of determinism. Later, another Paṇdit presented the rājā with a *shatranj* (chess) board which provided proof of the principle of free will. In this way, the two games demonstrated that just as a man was unable to solve the problems of determinism and free will through logical and philosophical arguments, so too he could find clues to the game of nature through arguments and practical games.

Nard (draught)[2] reached Arabia in the first century AH (eighth century AD) and *shatranj* (chess) reached later in the second century AH (ninth century AD).

Iranians' Claim

The Iranians unjustly claimed that *shatranj* (chess) belonged to them as its origin was *hashtranj* which had 8 squares. The game of *shatranj* (chess) really belonged to India because its origin was *chaturang*.[3] But one should not forget[4] that the name the Arabs gave to it in their own tongue by a jumble of letters then current in both Iran and India was *shatranj*. The story goes that when the rājā asked the inventor of chess to name the reward he desired, he merely said, 'Sir, put one grain of wheat on the first square and on each square double the grains on the preceding square and in this way fill the board.' The Arab historian Yaqubi and many others calculated the total number of grains required to fill the chess board and described the astronomical figure in their own writings.

This problem was also tackled by the Indian mathematician Abdul Hamid Ghaznavi[5] during Muhammad Tughlaq's reign by an interesting method. When the grains on a square are double of those on the immediately preceding square, no explanation or justification is given, but the method may be more amenable to a modern computer as it involves a lesser number of operations. Here it is:

First step : 1st half = 32 2nd half = 16
3rd half = 8 4th half = 4
5th half = 2 6th half = 1

Second step : 1st square = 4 2nd square = 16
3rd square = 256 4th square = 65526
5th square = 4294967296
6th square = 18446740737O9551616

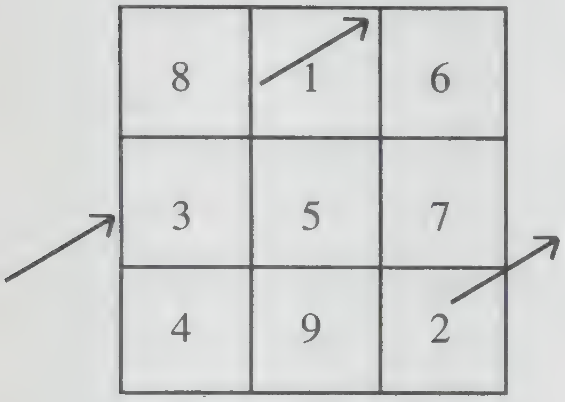
Third step : 6th square ≠ 1

The total number of grains on the chess board = 18446744073709551615.

Magic Squares

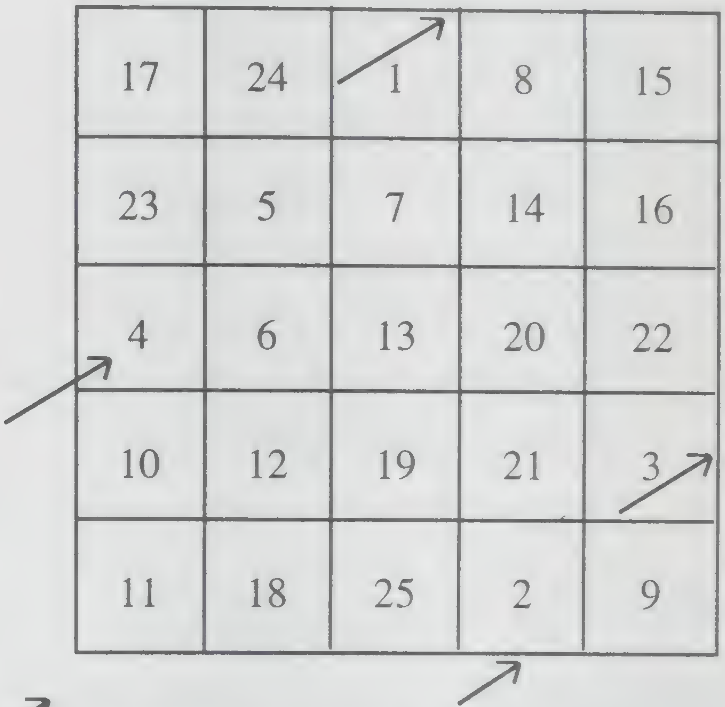
Construction of magic squares is a very old game. Magic squares were used in India as charms as early as in the first century AD. A reference to them is found in the earliest tāntrik literature. The mathematician Nārāyaṇa Paṇḍita (fourteenth century AD) rescued this game from tāntrism, and wrote a chapter on the construction of magic squares in his *Gaṇita Kaumudi*.[6] He gave some examples of magic squares like (a) 3 × 3, (b) 5 × 5, (c) 7 × 7 and (d) 9 × 9, as depicted below:

(a)



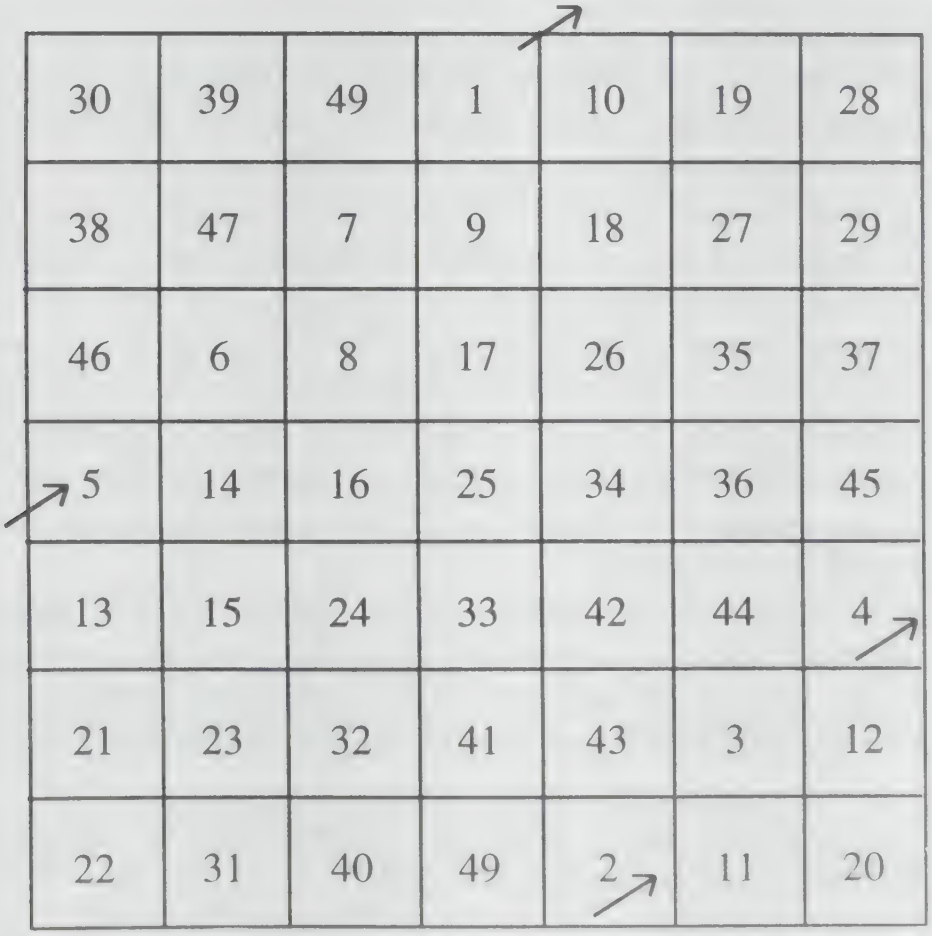
8	1	6
3	5	7
4	9	2

(b)



17	24	1	8	15
23	5	7	14	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

(c)



30	39	49	1	10	19	28
38	47	7	9	18	27	29
46	6	8	17	26	35	37
5	14	16	25	34	36	45
13	15	24	33	42	44	4
21	23	32	41	43	3	12
22	31	40	49	2	11	20

(d)

47	58	69	80	1 ↗	12	23	34	45
57	68	79	9	11	22	33	44	46
67	78	8	10	21	32	43	54	56
77	7	18	20	31	42	53	55	66
↗ 6	17	19	30	41	52	63	65	76
16	27	29	40	51	62	64	75	5 ↗
26	28	39	50	61	72	74	4	15
36	38	49	60	71	73	3	14	25
37	48	59	70	81	↗ 2	13	24	35

Rules for Filling Odd Magic Squares

In each of the above figures, begin with the middle cell of the top row and write 1 in the cell. If you proceed along the outward drawn diagonal of the cell (indicated in each figure by an arrow-head), this leads you beyond the square. Now if the squares were wrapped around a cylinder, you would get into the lowest cell of the next column. Therefore, write 2 in it. Then proceed again in the direction of the above outward drawn diagonal and write the next successive numbers 3, 4, 5, etc. in the cells thus encountered. Then you would again reach a cell which leads you beyond the square. Again imagine that the square is wrapped around a cylinder. In this way, when you reach the first cell of the next row, write the next number in the cell, and then proceed again in the direction of the above outward drawn diagonal. Continue the above process till all the cells are filled. Whenever the above process leads you to a cell which is already occupied by a number, write the next number in the cell below and proceed in the direction of the diagonal.

It will be easily seen that the above squares may also be filled by proceeding in the direction of the other outward drawn diagonal of the middle cell of the top row. Similarly, the above process may also be started with the middle cell of the bottom row or with the middle cell of the first or last column. Thus an odd square can be filled up in eight ways to form a magic square.

The four magic squares have been filled by the sequence of natural numbers, but alternative[7] methods are also given in *Gaṇita-Kaumudi.*

Even Magic Squares

In this case the rows and columns of the magic squares are even. For example, the 4 × 4 magic square of natural numbers with each of its columns totalling 34 is constructed by means of numbers forming arithmetical progression, or by 4 sets of 4 continuous numbers belonging to the same arithmetical progression. The method as given by Nārāyaṇa in *Gaṇita-Kaumudi*[8] involves determining numbers in their order as follows:

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16

Now write the numbers in a square directly and inversely as in figure (a) below. If in the upper half of the square (a) you interchange the numbers in the last two columns, and in the lower half interchange the numbers in the first two columns, you get the square (b).

(a)

1	2	3	4
8	7	6	5
9	10	11	12
16	15	14	13

(b)

1	2	4	3
8	7	5	6
10	9	11	12
15	16	14	13

Now fill the numbers in the first and second rows of square (b) in a 4 × 4 square by knight's move as in chess, starting with 1 in the first cell and with 8 either in a contiguous cell or in the last cell. The numbers in the second half of the square (b) are filled similarly, so that the numbers 15 and 10 occupy cells opposite to 1 and 8, respectively. We can thus obtain the following four magic squares.

1	8	13	12
14	11	2	7
4	5	16	9
15	10	3	6

1	14	4	15
8	11	5	10
13	2	16	3
12	7	9	6

1	12	13	8
14	7	2	11
4	9	16	5
15	6	3	10

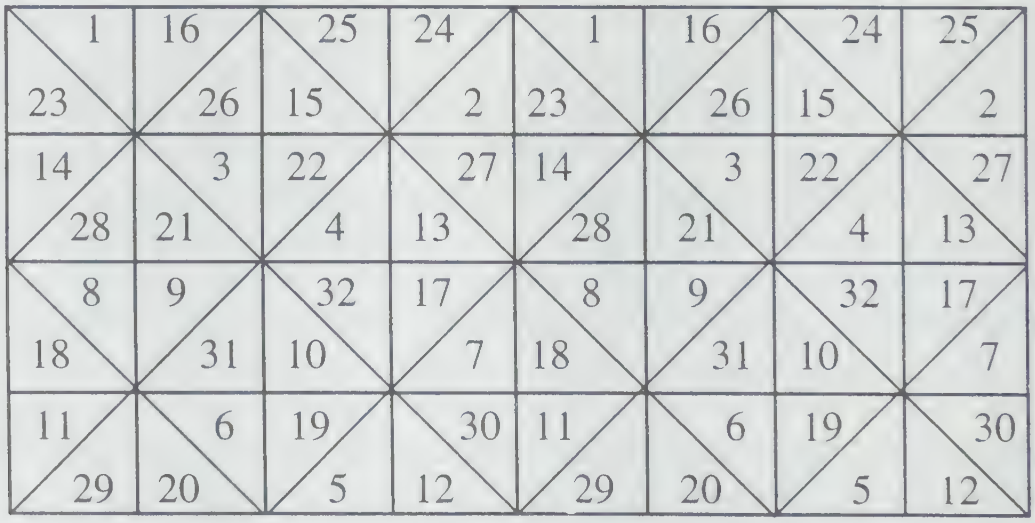
1	14	4	15
12	7	9	6
13	2	16	3
8	11	5	10

Magic Rectangles and Squares

Nārāyaṇa showed how to construct rectangles in which the sums of rows and columns were different. For example, he took a 3 × 4 magic rectangle,[9] whose rows added up to 132 and columns 66.

1	16	25	24	2	15	26	33
28	21	4	13	27	22	3	14
8	9	32	17	7	10	31	18
29	20	5	12	30	19	6	11

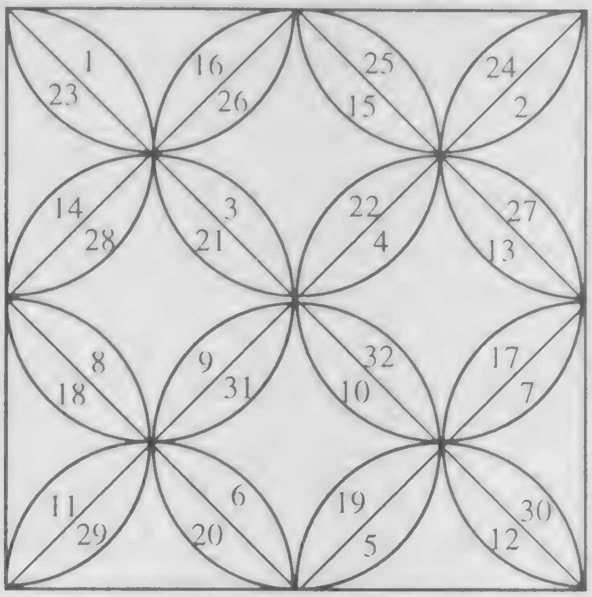
It has been shown that based on this rectangle, many other magic figures could be constructed. For example two types of magic figures, Maṇḍapa and Padma (lotus) as given below:



1 23	16 26	25 15	24 2	1 23	16 26	24 15	25 2
14 28	3 21	22 4	27 13	14 28	3 21	22 4	27 13
8 18	9 31	32 10	17 7	8 18	9 31	32 10	17 7
11 29	6 20	19 5	30 12	11 29	6 20	19 5	30 12

Maṇḍapa

In the Maṇḍapa, any set of 8 numbers occurring together, horizontally, vertically or diagonally sum up to 132. The 8 numbers lying in a square also have the same total. There is cylindrical symmetry, i.e. if the figure is rolled on to a cylinder, any continuous 8 numbers or the 8 numbers lying in a square will total 132. It is easy to find 26 sets of 8 numbers with the same total 132.



Padma

In the Padma, any set of 8 numbers taken vertically, horizontally or in any 4 leaves symmetrically situated will total 132. There is cylindrical symmetry. In this case 32 sets of 8 numbers having the same total can be easily picked out.

Other Varieties of Magic Figures

Indian Muslims also constructed many magic squares and similar figures, but there was nothing akin to tāntrism here. They did represent charms and amulets but there was no secrecy about them. Shukla[12] has given a few examples of such figures, which include *Dupaya* ('two-legged'), *Sulsi* (3 × 3), *Ruba'i* (4 × 4), *Khamsi* (5 × 5), *Musaddas* (6 × 6), *Musabba'* (7 × 7), *Musamman* (8 × 8), *Mustassa* (9 × 9), and *Ma'shshar* (10 × 10). Sometimes these were so large as to have 100 cells in a row or column.

The following is a Dupaya square with its rows and columns adding up to 12.

3	8	1
2	4	6
7		5

To construct a Dupaya square, divide the given total by 12. Fill the cells with the quotient increasing by itself in every next cell as you proceed. In case the division by 10 yields any (non-zero) remainder it is to be added to the number in the sixth cell. For example, let the total be 786. Division by 12 yields 65 as the quotient and 6 as the remainder. This gives the following square:

195	526	65
130	260	396
461		325

The following is the Sulsi square with each of its rows and columns adding up to 15.

4	9	2
3	5	7
8	1	6

To construct a Sulsi square, subtract 12 from the given total, then divide the remainder by 3 and with the quotient fill up the 9 cells of a 3 × 3 square until the whole square is filled up. The filling may be started from the central cell of a bordering row or column depending on the elements earth, water, air or fire, as shown below:

Air

2	7	6
9	5	1
4	3	8

Fire

4	9	2
3	5	7
8	1	6

Earth

6	7	2
1	5	9
8	3	4

Water

6	1	8
7	5	3
2	9	4

To construct a Ruba'i square, deduct 30 from the given total, then divide the remainder by 4, and with the quotient fill up the 16 cells of a 4 × 4 square. If 1 remains over, add 1 to the 13th cell; if 2, add 1 to the 9th cell; if 3, add 1 to the 5th.

With total 34, there will result four Ruba'i squares depending on the elements, namely, earth, water, air and fire, as depicted in the following figures:

Earth

8	11	14	1
13	2	7	12
3	16	9	6
10	5	4	15

Water

14	4	1	15
7	9	12	6
11	5	8	10
2	16	13	3

Air

15	1	4	14
10	8	5	11
6	12	9	7
3	13	16	2

Fire

1	14	15	4
8	11	10	5
12	7	6	9
13	2	3	16

The methods of constructing Khamsi[13] (5 × 5 square), Musaddas (6 × 6 square), Musabba' (7 × 7 square), Musamman (8 × 8 square), and Mustassa (9 × 9 square) with examples have been given and construction of Ma'shshar (10 × 10 squares) has also been suggested.

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11. *Ibid.* p. 57 (from *Siddhānta-Tatva-Viveka* ii, 68).
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13. *Ibid.* p. 61 (from *Siddhānta Śiromaṇi*, Gola 21-2, gloss).
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32. *Ibid.* p. 229.
33. Rizvi, *Indian Journal of History of Science,* 19(1), p. 84.
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6. Shukla, Kripa Shankar, IX, pp. 250-1 (from *Gaṇita Kaumudi*).
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CHAPTER IV

Ideas of Time and Space

Wazir Hasan Abdi

I. EARLY INDIAN VIEWS

Since man began to wonder, he must have asked the questions: 'What is this world?' 'Where is it situated?' 'Since when has it existed?' Amongst the earliest seers who guessed answers to these questions through intuition were our own ṛṣis, whose pronouncements are preserved in the *Ṛgveda*. It is generally believed that the *Ṛgveda* is the most ancient book whose main contents were composed about 4500 years before the birth of Christ. The oldest Greek classics *Iliad* and *Odyssey* of Homer were written about four to five hundred years later.

Ślokas from Vedas

In the early period of *Ṛgveda*, the world of the universe was visualized on the pattern of a house, where gods and goddesses dwelt side by side with human beings and animals. Ṛṣis believed that just as man had to build a house, the gods also had to build a universal one. The only difference was that while man built houses for a specific purpose, the gods did not need a purpose to build. Indeed, to build was a natural rule which applied to everyone.

Since early Indians used to build houses of wood for their own living, so the sages conjectured that the universal house (the universe) was also made of wood. However, they wondered:[1]

> What was the tree: What in sooth produced it from which they fashioned the Earth and Heaven?
>
> These Twain stand fast and wax not old forever:
> those have sung praise to many a day and morning.

The *Ṛgveda* did not give any single god or deity the credit of being the sole architect or creator of the universal house, but asserted that all gods—Varuṇa, Indra, Savitara, Tavistara and others—worked together to build the universe.

In fact our ṛṣis believed that the deities were not basically different from human beings, except that they were omnipotent. As Archibald Gough has remarked,[2] 'Indian faithfuls seek help from the Deities of *Ṛgveda*, manifestations of Nature and mythological concepts but do not think themselves different from them. All these are supposed to be Omnipotent Beings, who are appeased through *mantras*. However, there is no element of spirituality in these prayers and there is no desire for happiness in the other world or the next birth.' For example, in a hymn to Māruta[3] it is stated:

> Gods, send us happiness and make us wealthy, letting us singers propose, O ye Māruta! Bethink you of our praise and our friendship: Ye from of old have riches to vouchsafe us.

Atharvaveda is our fourth and the last Veda. Most of its *ślokas* were composed about 500 years after completion of the *Ṛgveda*. It contains mostly prayers, *mantras*, and invocations which give an idea of the faith current at that time. It is the beauty of Indian culture that whenever any religious or cultural capital reached India it was adopted and preserved: it became an integral part of Indian civilization. And as such, *Atharvaveda* contained the religious faith of both Aryan and non-Aryan practices. It also contains prayers for happiness and prosperity and for worldly goods without any desire for salvation or freedom from rebirth. For example, in a prayer invoking the Earth, the faithful said:[4]

> May my Motherland (Earth), bearing folk speaking different languages, holding different religious views, treating them all as residents of the same house, pour like a constant cow that never fails, a thousand streams of treasure to enrich me.

In another hymn[5] the Earth was invoked while similes of a cow and a calf were used:

> Earth is the cow, her calf is fire. May she with her calf fire yield me food, strength, nice resolve, noble life, offspring, plenty and wealth. This is our excellent prayer.

Skambha and Kāla

Besides prayers for happiness in this world, hymns of *Atharvaveda* gave importance[6] to 'Omnipotent Beings, like Skambha and Kāla'. According to some *ślokas* they produced Hirangarbha from which the Universe was born. Earth, Heaven, Atmosphere and the six directions were strengthened by Skambha. Fire, water, air, earth, sky were all contained in Skambha and it itself was contained in everything. It was the boundary which separated the finite from the infinite, the Earth from the Sky, and made them stay in their respective places.

Kāla[7] was said to be the 'first Being. It is the mover of whatever was and whatever will be. The vast Earth and six directions exist due to Kāla. The Sun rises in Kāla and again retires into it. The heavens also exist in Kāla and it is Kāla that envelops the entire universe. Kāla has always existed and its place is in the highest sky.'

In some hymns of *Atharvaveda* the description of Kāla was made more explicit. For example:[8] 'The Kāla carries along seven wheels, seven are its naves, and immortality is its axle. The self-same Kāla revealing all these worlds, is truly known to be Primeval Lord.'

In the above hymn, the entities were interpreted by a modern Indian writer[9] as 'six pairs of months and three Malmas, i.e. intercalary months, and seven naves; seven seasons of the year... or parts of time, i.e. *kṣaṇa hira, mahurta, prahara, dina, rātri* or *ahorātra, saptāh, pakṣa, māsa, ṛtuayan, samvatsara'*.

In another hymn, Kāla was claimed[10] to pervade, 'all the spheres, he also thoroughly surrounds Being Father, the Creator becomes their Son, the protector, No other energy is greater than He'. A modern writer explains the meaning of this hymn as follows:[11]

> The Father becoming the Son seems to be an enigma. But God is naturally the Father. The Son's duty is to look after and remove all difficulties and troubles of his parents, so in this restricted sense of taking care of His own creation, He is called the Son, or it may point to the days, nights, weeks, fortnights, months, year, parts of the time i.e. Kāla from the earth, the Moon and the sun, created by God, the Kāla.

Early Speculation

In these *ślokas,*[12] 'no deep philosophical explanation of Skambha or Kāla has been given. Both have been called primeval and their properties appear to be the same.' However, these hymns are of great importance in the history of philosophic speculation. The *ślokas* of *Atharvaveda* were composed about 600 years before Christ's birth, about the time the Greeks had begun to search for the prime elements behind the Universe. Some claimed that Water was the first principle, others thought it was Fire, while still others claimed it was Earth or Air.

But concepts like Time and Space as the beginning and the end of the Universe were accepted for the first time in these *ślokas.* The concepts of space in the form of Skambha and of Time in the form of Kāla were enunciated in simple and plain language, which the faithful of those times could easily understand. There were no complications of the kind that appeared in the later Indian philosophies. Moreover, these concepts were not merely simple products of the human mind but were based on feelings that stemmed from experience, a state more akin to intuition rather than to deliberate, rational thought. The relation between cause and effect was not explained but on the whole these concepts had played an important role in the evolution of Indian and Greek philosophies.

Philosophical Conceptions

Time and space were mentioned in the Vedas in anthropomorphic from, but their descriptions gave birth to philosophical speculation. According to Radha Krishnan,[13] 'The sixth century BC marks the beginning of systematic philosophy in India, and by the first century BC, the term *Anvikṣiki* is replaced by *Darśana.* Every enquiry starts in doubt and fulfils a need.' He further stated:[14]

> Amongst the systems of thought in *darśanas,* six became more famous than others, viz. Gautama's Nyāya, Kaṇāda's Vaiśeṣika, Kapila's Sāṁkhya, Patañjali's Yoga, Jaimini's Pūrva Mīmāṁsā and Bādarāyaṇa's Uttara Mīmāṁsā or the Vedānta.
>
> The Sāṁkhya[15] system represents a notable departure in thought from what may be called the formalistic habit of mind . . . It undermines the foundation of spiritual religion by substituting evolution for creation. The world is not the act of a creator God, who summoned up by a single fiat of his will a world entirely distinct from himself but is a product of the interaction between an infinite number of spirits and the ever active *prakṛti,* or the potentiality of nature.

Sāṁkhya Darśana, the oldest philosophy of India, was founded by Kapila about eight centuries before Christ. This philosophy had a great influence on Gautam Siddhārtha and, later on, it was itself greatly influenced by Buddhist philosophy. It left deep impressions on all our ancient literature, specially *Manu Smṛti, Mahābhārata* and *Purāṇas.*

Richard Garbe[16] claimed that 'some important Greek philosophies especially Neo-Platonism and Neo-Gnosticism had also been deeply influenced by this philosophy'. The writings of Kapila were lost, but about a thousand years later in AD 200 Īśvarakṛṣṇa compiled his *Sāṁkhya Kārika* based on Kapila's teachings, and is generally treated as the basic treatise on Sāṁkhya.

Basics of Sāṁkhya

In analysing the existence of the Universe, the founders of Sāṁkhya did not ask: What was in the beginning? Or what will be in the end? Because these questions could not be truly answered at all. According to them, the universe had always existed as *Prakṛti;* and according to the chain of Cosmic Evolution, it sometimes appeared and sometimes disappeared but it could be brought to 'existence' from non-existence, because[17] without the material, how could anything be formed. For example, if the cream was not already hidden in the milk, how could it be produced? According to this philosophy, the universe had not come into existence due to the will or fiat of any creator but it was the result of interactions between *Puruṣa* (which could be called the Spirit) and the *Prakṛti* (Nature). *Puruṣas* were uncountable but were independent of not only *Prakṛti* but also of one another. However, *Prakṛti* was one and indivisible. The influence of *Puruṣa* was just like the proximity of a magnet which attracted iron. In other words, nearness of *Puruṣa* compelled *Prakṛti* to start the process of production. This type of attraction resulted in creation, but *Puruṣa* itself has no connection with creation.

The essence of everything in this universe was *Prakṛti*,[18] which 'is inherent in everything but has no shape of its own. It has neither beginning nor end.' It had three *Guṇas*:[19] (i) *Sattva*, the tendency to manifestation: (ii) *Rajas*, the tendency to act ; and (iii) *Tamas*, the tendency to non-manifestation and non-activity. These *guṇas* had always existed; they always combined separated and then combined but again, never merged into each other. There was once a sort of equilibrium among these *guṇas*, but the shadow of the *Puruṣa* produced a movement in them leading to the process of Cosmic Evolution.

'The Sāṁkhya philosophy believed in two processes: Evolution and Dissolution. Appearance of *Prakṛti* resulted in Evolution and the disappearance of its arrangement led to its Dissolution. The difference between the 'apparent' and the 'inherent' was only the result of different arrangements. However, if the 'apparent' and the 'inherent' were added, then the total of *Tamas* and *Rajas* remained the same, only the arrangements changed. Nothing new came into existence, only new forms appeared. Similarly, in dissolution, nothing was destroyed, only the continuous change of arrangements reestablished a sort of equilibrium. However, their contradiction did not come to an end. Such a state was called *Pralaya*. *Prakṛti* remained dormant and sometime in the state of *Pralaya*, but later on when once again the shadow of *Puruṣa* fell on it the processes of Evolution and Dissolution restarted. This process had always been going on and would always continue.

In this way, through the processes of Evolution and Dissolution, countless things appeared or disappeared by the combination of gross elements without there being any increase or decrease in the total available matter and energy. According to Sāṁkhya,[20] Cause and Effect were in fact two forms of energy which resulted from material cause or a set or causes. It was the inherent *Rajas* which, being released, appeared in the form of Effect with a new arrangement. The appearance of the result was in fact a journey from the Possible Existence (i.e. the future) to Actual Existence (i.e. the present). But to move material cause, concomitant action and favourable conditions were also necessary. However, when the conditions were not favourable, the different deserved properties did not appear. For example, a sculpture was already present in stone, but it could appear only through the medium of the sculptor. Steam was already inherent in water but the physical factors for its appearance were produced by the action of fire on water. The concomitant conditions were, according to Vyāsa, place (*Deśa*), time (*Kāla*) and form (constitution).

The Sāṁkhya philosophy[21] thus concluded:

> Change is taking place everywhere and at every moment. We cannot twice step into the same stream, since the waters do not remain identical for two moments together. It is also true that the same individual does not twice step into the same river, for he has meanwhile changed even as the river has done. Out of all things and states, and out of this changing process, the mind of man constructs the role of causality, by means of the relation of antecedents and consequents.

Time and Space

According to Indian philosophers, man perceived changes in a sequence on the basis of which the mind made the journey precedent and antecedent. Time was only the name of the feeling of what event took place earlier and what occurred later. All changes depended upon the movement of gross element in space (*Deśa*). The motion from one point to the nearest was taken as an absolute unit of change. This unit was called *Kṣan* (instant) which had no parts. According to Vyāsa,[22] the continuous flow of these was a *Krama* (sequence). Moments and sequences of these could be combined into a *Vastu* (real). Thus, time, being of this nature, did not correspond to anything real, but was a product of the mind, and flowed as a result of perceptions or of words. But the moment was an objective and rested on the sequence. The sequence (*Krama*) had for its essence an uninterrupted succession of moments which was called Time (*Kāla*). Two moments could not occur simultaneously, since it was impossible for a sequence of two events to occur simultaneously. A sequence thus occurred when a later moment succeeded an earlier one.

The movement of *Tanmātra* was perceived by change inside space also. The Sāṁkhya philosophy believed in two aspects of space: (i) *Dik* (i.e. a relative arrangement of material points); and (ii) *Deśa* (i.e. expanse) which would only be measured in terms of minimum qualities inherent in *guṇas* of *Prakṛti*. In fact, *Deśa* emanated from *Ākāśa* into which it merged in the reverse process of dissolution. And *Ākāśa* itself in *Pralaya* took the form of *tamas guṇa* of *Prakṛti*.

These principles of Sāṁkhya flowed from the principles of Cosmic Evolution. According to this philosophy, the real origin of this world was material and was the result of the conflict between the *guṇas* of *Prakṛti*. However, in explaining the Prime Movement it became inevitable to introduce a non-material existence and an imperceptible being like *Puruṣa*.

But Dale Riepe[23] wondered: 'If *Puruṣa* can also be supposed to be eternal like *Prakṛti*, why did Sāṁkhya not accept Movement also to be eternal. Possibly in this way there would have been no need of *Puruṣa* and logical contradiction would have been reduced. Besides, on the one hand *Puruṣa* is believed to be outside the Universe while on the other hand exists in the form of Individual Souls.' However, there were no answers to the questions that when Movement started how did *Puruṣa* confine itself in the conglomeration of *Prakṛti* consciousness and how did it acquire understanding.

The result of these contradictions was that, in later times, some followers of Kapila began to believe that *Puruṣa* was the Prime Mover, or *Īśvara* of all. It was difficult for many people to understand that there was something material which had always existed, in its different types of *Tanmātras* and gross elements, whose combinations took in individual *Jīvātmās* (souls). They therefore came to the conclusion that[23] *Puruṣa* was the eternal Father and *Prakṛti* the Mother. Some believed that *Puruṣa* was in reality the great soul (absolute man) and *Prakṛti* was *Śakti* or his consort. Accordingly, Brahmā, Viṣṇu and Śiva were recognized as the *Puruṣas* in different *Purāṇas* on different occasions. For example, *Agni Purāṇa* claimed that *Param Puruṣa* Viṣṇu, entered into *Prakṛti* and changed its form. Some Tāntrik sects identify Śiva as *Puruṣa* and Jagdambā (mother) as *Prakṛti*.

It is significant that the Sāṁkhya philosophy enunciated for the first time, the principle that energy was never destroyed but was always dissipating, as a result of which the evolutionary cycle never came to an end. However, this resulted, according to Brijendra Nath Seel,[24] in energy not being deduced on a purely metaphysical level. Some scholars believed that the principle of *Tanmātra* and gross matter in the transformation of material objects was influenced by the chemical industry of India. In later times,[25] whichever Indian thought process accepted the external world as a measure, to some extent could not avoid Sāṁkhya *darśana*. Radha Krishnan[26] cautioned against accepting the mechanical evolution of Sāṁkhya philosophy: 'The different principles of the Sāṁkhya system can not be logically deduced from *Prakṛti*, and they seem to be set down as its products, thanks to historical accidents. There is no deductive development of the products from the one *Prakṛti*. Vijñānabhikṣu is aware of this defect, and so asks us to accept the Sāṁkhya account of evolution on the authority of the scriptures. But this is to surrender the possibility of philosophized explanation.'

In similar situations Radha Krishnan[27] warned: 'The one danger we have to avoid is least faith should furnish the conclusions of philosophy.'

Vedānta Philosophy

Today the philosophy which is sometimes presented as the most representative of Indian thought is Vedānta. Vedānta means the philosophy of *Upaniṣads*. The earlier *Upaniṣads* were supposed to be appendices or the last part of the Vedas.[28] The *Upaniṣads*, as Radha Krishnan observed,[29] did not yield any consistent view of the Universe. The authors were many and not all of them belonged to the same period, and it was doubtful if they all intended to set forth a single view of the Universe. Even then, those who believed the Vedas to be heavenly and eternal tried to prove that *ślokas* were the fountain-head of all knowledge.

Bādarāyaṇa presented an organized system of thought by composing *Brahma Sūtra* in which the problems of *Brahman, Ātman*, Universe, and *Mokṣa* were discussed. Not much is known about the life of Bādarāyaṇa, but because in *Brahma Sūtra* he criticized almost all *āstika* and *nāstika* Indian philosophies, it was conjectured that he was born about 200 years before Christ. In all there were 555 *sūtras*, which were formulae each consisting of two or three words. *Sūtras* were not easy to understand. Later on many commentaries of *Brahma Sūtra* were written of which Śaṅkara's commentary or *Bhāṣya* was the most important. It was generally believed that Bādarāyaṇa's views were correctly presented in Śaṅkara's *Bhāṣya*.

Śaṅkara was born in Kaladi (Kerala). He became a *sanyāsin* when he was eight years old. He is said to have completed writing *Bhāṣya* at the young age of 12. His teachings made a mark on the evolution of India's religious life. The basis of his principle was that it was not always possible to arrive at truth through logic and discussion. The real truth could be achieved through a revealed *grantha*, specially the *Upaniṣads*. Thus intelligence, perception and analysis were important only in the sense that they could be used for understanding the real meaning of *Upaniṣads*. Surendra Nath Dasgupta[30] was of the view that Śaṅkara did not propound any philosophy in the sense of modern terminology. His main achievement was the verbatim presentation of whatever revealed truths were taught in the *Upaniṣads*. The problems that Śaṅkara himself did not raise were later on considered by his disciples, without which Vedānta could be called a metaphysical system.

According to *Brahma Sūtra*, the *Puruṣa* and *Prakṛti* of Sāṁkhya were not two separate and independent beings: they were two *Rūpas* (aspects) of the same truth. The One that was mentioned in the *Upaniṣads* was the one and only one *Brahma*. He could be called *Tattva* and *Paramātmān* (absolute spirit). He might be remembered by whatever name but he was *Nirguṇa* (free from attributes) and only he was the Real.

Śaṅkara considered it wrong to believe that He was the deity or creator. Creation[31] had been mentioned in the holy books only to prove that *Brahma* and *Jagat* (Universe) were one and the same, because if he had created the Universe with something else then the existence of someone else would have to be accepted; and this would have been against his *advaita* (oneness).

According to Śaṅkara,[32] the individual souls were not separate from Him. *Jīvātma* (animal, soul) was a part of *Paramātmā* (absolute soul), just as a spark was part of fire. No beings could be the existence of *Brahma* simply because He was everyone's soul. No living being could deny the existence of his own *Ātman*. Man never thought that 'I am not'. If the existence of *Ātman* was not known, everybody would have though that 'I am not'. Naturally, *Ātman* whose existence was known to everybody was the *Brahma*, but his existence could neither be proved nor felt, because being the *Sākṣi* (observer) He could never be the object. In the words of Sampūrṇānand:[33] 'Understanding takes place only when the understanding person and the object of understanding both exist. When only *Ātman* remains, who will understand whom?' Even then only when the *Jñānis* (learned devotees) withdrew their perceptive organs from external things in a state of *Samradhan* (perfect tranquillity) and concentrated on their own inner self could they recognize the *Nirguṇa Brahma* (the attributeless) in their own self; then they gained the knowledge that the multiplicity of *nāmarūpa* (name and form) in the Universe was only illusion and ignorance. Indeed, everything was *Brahma* only. This was the Advaita,[34] (non-duality) or uniqueness in which there was no place for dualism. In the terminology of Sufis, this was the stage of *Ana-al-Haque* (I am the Truth) and *Hama ust* (All is He).

According to this principle of Vedānta, time and space were not real. There were only things belonging to our limited individual consciousness which were related to human feelings and things. Only on the basis of these, could different things be distinguished, but the real got eclipsed. The difference of places, instants and happenings was the external world (*Jagat*). The real was timeless, spaceless, and absolute perfection which needed neither before nor after.

Towards Practical Philosophy

The propounders of this neo-metaphysical philosophy had themselves felt that it was suitable only for those who could reach the highest stage of spirituality and knowledge. Ordinary human beings[35] only wanted happiness and prosperity in their worldly life and, if there was any other life, after the present, they were desirous of greater happiness there as well. They met people of different natures all their lives and had to go through all sorts of pleasure and pain, how then could they understand that differences in this external world did not exist at all? To get over this difficulty, therefore, *Vyavhārik darśanam* (practical philosophy) was also propounded for the common people.

According to this practical philosophy, the body was like a plant which germinated from the seed, grew spread and then withered away; yet, something remained. The seed disappeared from view but produced another plant. The seed germinated due to the rains but what grew depended on the seed alone: that is, only paddy grew from paddy, not wheat. For a man, a seed was like his *karma* (action or doing) and *Īśvara* or God was like the rain, which was the cause of the growth of the plant. A logical inference from this principle was that the *Saṁsār* (a chain of appearances) had no beginning. Howsoever back we could go the condition of every birth was determined by the condition of some earlier birth.

But according to Paul Duessen,[36] this assumption did not agree with the hypothesis of ancient *Upaniṣads*, according to which 'That Unique one only is eternal. It is He who created this Universe.' But *Vedānta* laid stress on the fruits of *Karma* and *Saṁsār* being eternal. And to avoid this contradiction, *Vedānta* came out with a formula that the *Brahma* and the Universe were *Anannya* (non-different). The real existence was that of *Brahma* and the external Universe was only a manifestation. According to Śaṅkara, Manifestation and Existence were different, because the former had no existence of its own, but we could not even call it non-existent. As Debi Prasad Chattopadhyaya[37] asserts: 'This is the very difficulty of an idealist. It is not possible for him to reject practical life totally and similarly to accept it without hesitation is equally impossible.' Accordingly, Vedāntists believed that the Universe was neither being nor non-being. The real was to be free from self-contradiction, but the world was full of contradiction. The world of space, time and cause was thus not self-explanatory. There was no principle of reconciliation in the finite world by which its difficulties could be dissolved. Space, time and cause, which were the forms of all experience, were not the ultimate; the real was obscured by them. If we got beyond the distinctions of places, moments and events, the world of diversity would collapse into a single unit. Experience cast in the moulds of space, time and cause was phenomenal only. The real was what was present at all times: it was that which ever was, is and will be.

Śaṅkara was of the view that the formation of the Universe was like the appearance of a snake from the rope for the viewer's eye. The juggler's jugglery caused the rope to disappear from the eyes of the onlooker and then imposed the snake shape on it. There were two aspects of this game: (i) *Āvaraṇa* (to conceal the real) and (ii) *Vikṣepa* (to create the feeling of a new form). For *Brahma* the formation of the Earth was only a play or *līlā*. In this play, he applied his special attribute which was called *Māyā*. *Māyā* itself was neither existent nor non-existent, but it could endow anything which had no existence with a temporary existence or a practical actuality. *Māyā* had no existence separate from the *Brahma,* who did not shape the means *Māyā* employed to the external world appear through *Vikṣepa*. In other words, the *Mūla* (basic) cause of the Universe was *Brahma,* and the *Upādān* (material) cause was *Māyā*; but this Manifestation was not real, it was *Vivarta* (only a psychological) reality. Being associated in this action, the *Brahma* also appeared *Saguṇa* (with attributes). The *Saguṇa Brahman* was called *Īśvara,* the creator of the Universe and the organizer of *Saṁsār*. But at the highest stage of knowledge even the *Īśvara* was not real: only the *Nirguṇa* (attributeless), *Brahma* was the real one.

Śaṅkara said that the *Jagat* (Universe), was always in movement and changes appeared only due to *Parispand* (fine universal vibrations). The elements themselves did not possess this potentiality because they did not have sense, without which no movement was possible. Thus, it could be inferred that after bringing in the elements, the *Brahma* himself entered them, because he himself was absolute consciousness. According to the *Upaniṣads,* 'That One imagined to become many by expanding His own self, and thus created the elements and entered them with *jīvātma* and spread the *nāmarūpa prapañcha* (network of names and forms).'

But in certain *Upaniṣads, Ākāśa* also was said to be the cause of *Nāmarūpa*. On the other hand, according to some *Upaniṣads, Ākāśa* was only an element, which could not be taken as finer than other elements. *Maitranya Upaniṣad* uses this word as being synonymous with expanse or space. Another *Upaniṣad* said that *Ākāśa* was self-born. The sun, the moon, the stars were all within it. Since Śaṅkara believed that all *Upaniṣads* were heavenly books he did not find any contradiction in these definitions. He came to the conclusion that, in the higher sense, *Ākāśa* meant *Brahma,* only He who was beyond the conglomeration of *Nāmarūpa* (name and form). However, according to *Vyavahārik Darśana, Ākāśa* was the first creation. It was space and vacuum also, besides being a fine element. Thus, Śaṅkara believed *Ākāśa* to be between material and non-material.

Śaṅkara's view about Kāla (Time) was of the same nature. According to him, the relation between Brahman and *Māyā* was known as Kāla, which could be taken as existent in the sense that it was present in *Māyā* and Brahman, otherwise it had no existence of its own. *Kāla* had always existed along with *Māyā,* but it was not eternal; and similarly, *Māyā* had no beginning but it was eternal. *Saṁsār* had no beginning but it had a definite end; similarly, *Kāla* never began but when all the *Jīvātma* (souls) become free and *Māyā* disappears, then *Kāla* would also come to an end. All things of this Universe would exist in *Kāla* and *Akāśa*. *Jīvātma*, *Māyā* and *Īśvara,* were beyond *Kāla* and *Ākāśa* (i.e., beyond Time and Space).

These principles of Vedānta attached more importance to the reality beyond, in comparison to the external world. Thus, a feeling was created that if human life was only a part of continuous innumerable lives, what could be the importance of a single life span. That is why Hajime Nakamura is of the view that the feeling of time becomes paralysed.[38] The fact is that Indians never tried to catch the concept of Time quantitatively. A sample of this confusion can be noticed in our languages[39] as well: for example, in Urdu and Hindi, the words *kal,* and *parsun* have two meanings, the same words expressing the past as well as the future. In Kashmiri, the word *parsun* is used not only for two days before but also for hundreds of years past.

As Śaṅkara's view spread in India, interest in natural sciences declined, and almost all matters were considered from the metaphysical point of view. In modern days, the principles of Advaiyavāda have been presented in metaphysical grab, to remove mental difficulties of supporters of capitalism, while some enthusiastic interpreters even tried to prove that modern science and Śaṅkara's view were identical. Ruth Reyna[40] said that 'the particle science of today is the practical shape of Advaita Vedānta and *Brahma* is thermo-dynamic equilibrium.' Kashi Nath was of the view that *Brahma* ought to be taken as 'Field of Force'. These beliefs should not be brushed off lightly. But this sort of mental make-up will not be helpful in philosophic or scientific developments. In the words of Baldev Upadhyaya:[41] 'Science has made all-round development depending upon pure intellectualism. Therefore Science should search for it new elements remaining impartial. It does not behove it to be a slave of religion or philosophy.'

Śaiva Siddhānta

The medieval period marked the culmination of theism. Nīlakaṇṭha wrote a commentary on *Brahma Sūtra* interpreting the work in the light of the Śaiva system. In this system the supreme reality was called Śiva, who was regarded as beginningless, uncaused, without defects, the all-knower, free from individual souls and the bonds which fetter them.[42] The world was considered to be undergoing change. Its material cause, *Prakṛti*, was unconscious like the clay, and could not organize itself into the world. The developments were not due to the elements, which were devoid of intelligence. *Kāla* or time was changeless, though it appeared to the observer as changing; it was a condition of all action but was not by itself an active agent. But if God was directly the cause, His independence and perfection might perhaps be compromised. It was, therefore, believed that God operated through His Śakti as His instrumental cause.

The principle of *Karma* worked in accordance with the spiritual ends of man. It did not frame the ends or make distinction between good and evil. These were laid down by an infinite Spirit, who with the aid of His Śakti (energy) also saw to it that man got his proper reward. As the jar had the potter for its first cause, the staff and the wheel for its instrumental cause, and the clay for its material cause, so had the world Śiva for its first cause, Śakti for its instrumental cause, and *Māyā* for its material cause.

According to Baldev Upadhyaya,[43] 'Śiva is everlasting, since he is not limited by Time. He is omnipotent. He works through his Śakti, which is not unconscious, but conscious energy—the very body of God.' He further stated:[44] 'Śakti, often called Umā, is but the reflex of Śiva, and not an independent existence. The Absolute in itself is called Śiva, and the Absolute in relation to objects is called Śakti. In the *Siddhānta*, Śiva is not only the Absolute of metaphysics, but the God of religion. He is the saviour and guru and he assumes this form out of his great love for mankind. He is the God of love.'

The *Saiva Siddhānta* analysed[45] the Universe into 36 *Tattvas* as against the 25 of the Sāṁkhya. The instrument by which the active soul observed the operations of *Buddhi* was called *Vidyā*. *Māyā* was the desire on which all experience depended. *Kāla* or time regulated experience and past, present and future. Time was not eternal for eternity was independent of time.[46]

Bhakti Movement

The ordinary toiling masses in medieval India were not much interested[47] in the labyrinth of metaphysics. The saints picked up the factor of Śaṅkara Vedānta that no human being was separate from *Brahma*, and used it to raise their voice against inequality and social and religious differences. It may be noted that almost all the saints during this period belonged to lower castes and were handicraftsmen: Kabir was a weaver, Nāmdev a tailor, Sen a barber, Dādu a corder, Ravidāsa a cobbler, Tukā Ram a low-caste shopkeeper. They sang songs of hope in popular dialects, avoiding Sanskrit, the language of scholars, and tried to take the toilers out of the world of hopelessness. As Kṣti Mohan Sen has remarked:[48] 'At a time when experts of metaphysics were dividing themselves into Advaiyavāda, Dvaitavāda and Advaita-dvaitavāda just then cobblers, weavers and water-bag sewers sprang from the depths of social obscurity saying that all these formally concocted by mind are meaningless. The experts of metaphysics could not see from their deeper vision how much the world is full of truth, love, beauty and happiness.'

This powerful movement laid emphasis on unity and happiness of mankind. There was not much scope for metaphysical or philosophical studies, however, these later gained religious meaning and strength from the doctrines of Vallabha and the Caitanya movements.

Thus, it can be seen that in searching for an answer to the riddle of time and space, Indian thinkers started with the anthropomorphism of the Vedas, went through the philosophy of Sāṁkhya and Vedānta, and then came upon theism of the medieval period, most powerfully expressed in the sayings of the saints.

Cyclic Theory Time

The idea of continuous 'creation-destruction-creation' of the Universe is very old. Some *ślokas* of *Atharvaveda* indicate that the Universe comes to an end in a specified time, then creation takes place anew, followed by destruction again after a lapse of the same time. This change had always continued and would always continue. On the other hand, daily observations confirm that the revolution of seasons never changes. After a year comes to an end, the same seasons return and gradually keep on changing. In the revolution of the moon, darkness follows brightness and brightness follows darkness. Accordingly, combining this fact with other items of faith, represented in religious tales called *Purāṇas* (at about the time *Mahābhārata* and *Gītā* were composed), this article of faith became an important part of the religious life in India. Jain and Buddhist philosophies contained such ideas. In Vedānta, only a philosophic form was reiterated.

Ancient Indians believed that the deities lived on the North Pole. When the Sun shone over the northern hemisphere it was day on the North Pole; it was night during the remaining six months. The compilers of *Purāṇas* inferred from this that our one-year was a day, and night was *Ahorātri*, for the *Devatās* (gods). Accordingly, treating 360 solar years as one year they calculated that in a period of 12,000 years of the *Devatās*, a universal period or *Mahāyuga* was completed in which the Universe again returned to its original from. A *Mahāyuga* was also called *Catu Yuga*, and consisted of four yugas: *Kṛt* or *Satya*, *Tretā*, *Dwāpar*, and *Kali*. The *Kaliyuga* continued for 4,32,000 solar years; *Dwāpar* for 8,64,000 years , and *Tretā* for 12,96,000 years. *Kṛt* was the longest yuga with a span of 17,28,00 years. In each yuga man's moral, economic and physical life was determined by the same proportion. The initial period of *Mahāyuga* called *Kṛt* or *Satyayuga* was the best period, also called the period of Total Truthfulness. In this period there was no fear or disease of any sort; men had not to do work of any kind: the Earth itself supplied their needs; human life extended to 4000 years and the people led a life of simplicity, honesty and virtue. However, by the time *Kṛt* came to an end, greed took the place of honesty and people began to amass wealth. Due to this moral degradation three epochs, *Tretā*, *Dwāpar* and *Kaliyuga*, followed, each yuga worse than the preceding yuga. The life span of the people kept on reducing and wars, diseases, poverty and hunger kept on increasing. In *Dwāpar* half the population lived for 1000 years, leading a life of honesty, but in *Kaliyuga* hardly a quarter of the human population had any element of honesty left. In this period of violence, disturbances and riots very few people attained the age of 100 years.

Earlier, a *Mahāyuga* was believed to be the total age of the Universe. In the beginning of *Kṛt* itself creation took place and at the end of *Kaliyuga,* the whole Universe was destroyed by flood and fire. However, later on it was thought that *Mahāyuga* followed after *Mahāyuga,* at the end of which great destruction and havoc took place, but the Universe was not annihilated: after a certain period it again took shape and honesty and truthfulness began to appear. Then the three yugas also passed and annihilation took place once again through flood and fire. This process continued for a *Kalpa* or 1000 *Mahāyuga.* In the last *Kaliyuga* of *Kalpa* the sun's heat become too terrific that the entire earth became totally dry and the three *lokas* were burnt to ashes. In the end, heavy dark clouds appeared and it rained continuously for many hundred years. Water spread up to the sky. This destruction was called *pralaya* (Doomsday).

A period of 100 *Mahāyugas* or *Kalpa* was taken as Brahmā's one day. After that came Brahmā's night. During Brahmā's night, the Universe remained dormant and when the day began activity also started. Two *Kalpas* were taken as a day-and-night (or *Ahorātri*) of Brahmā. This process continued for 100 years of Brahmā's life (i.e. 72,000 *Kalpas*) continuously. Then came *Mahā Pralaya Kalpa* and Brahmā also died along with the Universe. This was followed by the birth of another Brahmā, and the process restarts as before.

The Brahmā mentioned in this theory of *Kalpa* should not be confused with the *Nirguṇa Brahma* of Vedānta. The Brahmā associated with yugas is only a *devatā,* made head of the Universe for a specified period. No one knows how many Brahmās have passed away and how many are still to come. According to *Viṣṇu Smṛti,*[49] one can count the grains of sand along the banks of Gaṅgā and the drops of rain, but it is impossible to count the number of past and future Brahmās. Anyway, the Brahmā associated with our age has passed only 50 years of his life and at present only the first day of the year is current. In this day or *Kalpa,* 456 *Mahāyugas* have passed. This is the *Kaliyuga* of the present *Mahāyuga* which began in 3102 BC in the night between 17/18 February at the end of the war of *Mahābhārata.* It will take about 4,27,000 solar years to the destruction of the Universe at the end of *Mahāyuga.* The remaining 155,518,026,186,903 solar years (after 1995) of our Brahmā's remaining life will be spent in the process of creation-destruction-creation of this *jagat.* Then some other Brahmā will create another Universe and for 311,040,000,000,000 solar years shoulder the responsibility of the *Kāla Cakra* (time cycle); he will also pass away and some other Brahmā will take his place; and so on and so forth. But in this interminable *Kāla Cakra* only *Nirguṇa Brahma* remains *Akṣar* (immortal), because He is the Absolute Existence.

The system of *Mahāyugas* was so important that all Indian schools of Jyotiṣa (Astronomy) accepted it, but continued to discuss the details. Indian experts of Jyotiṣa believed that the earth was still the centre of the Universe. All celestial bodies revolved round it in circles and beyond the planets was situated the sky of stationary stars, which covered a complete revolution in 36,000 solar years; which meant that the star visible today at a point in the sky would return to the same point after 36,000 years. On the other hand, the other planets, even after thousands of revolutions, would not reach the point where they are today, because every planet had its own movement.

A special factor about the *Mahāyuga* is that, in its beginning the Earth and the seven planets, i.e. Candra (moon), Budha (Mercury), Śukra (Venus), Sūrya (sun), Mangal (Mars), Bṛhspati (Jupiter) and Śani (Saturn) are collinear; they return to the same position at the end of the *Mahāyuga* as does the sky of stars to the same position where it was at the beginning of the Mahāyuga. In this period, the sun makes 43,20,000 revolutions, the moon 5,77,53,336, Mercury 1,79,37,060, Venus 70,22,376, Mars 22,96,832, Jupiter 3,64,220 and Saturn 1,46,568.

The ancient astronomers observed that whenever the sun, the moon and the earth stood in the same row, solar or lunar eclipse took place. Eclipses were always supposed to be important events and the time for misery to descend to earth. Indian astronomers therefore concluded that the appearance of all planets in one line was a supernatural event (i.e. the end of a yuga and the beginning of another). They accepted this theory in their practical astronomy. Accordingly, in classical Indian astronomy the positions of stars and planets were calculated on this very basis. Even today many jyotiṣa-ācāryas (astronomers) calculate the beginning of *Kaliyuga* on this basis, instead of Vikrama Samvat or the Gregorian calendar.

What was the basis of these ideas? Did these ideas originate in India itself or in other countries? For example, it was believed in Babylonia, Iran and Greece as well that the cycle of creation and destruction went on continuously, and that time returned to its original point after a revolution. Some Greek philosophers even believed that, after every new creation, the story of the earlier construction was repeated word for word: in any universal epoch, Socrates is born of the same parents, teaches in the same way and in a similar manner dies drinking the cup of hemlock! However, on the contrary, Indians believed that man could get rid of the cycle of life and death any time or even take birth in thousands of forms in the same yuga. Hence, it is difficult to pin-point where the cycle theory of time came from.

But one thing is obvious: the duration of different yugas has been calculated by the principle of 'sixty'. *Kaliyuga, Dwāpara, Tretā* and *Kṛtyuga*, respectively, are thus equal to 2 × 60 × 60 × 60, 4 × 60 × 60 × 60, 6 × 60 × 60 × 60 and 8 × 60 × 60 × 60 solar years; and a Mahāyuga is equal to 20 × 60 × 60 × 60 solar years. Seva Ram Menon[50] and David Pingree[51] are of the view that this principle of 'sixty' was discovered in Babylonia and later made use of by Indian ṛṣis for both short and long units of time. In our Jyotiṣa (astronomy), sixty days and nights together are called a *Ṛtu* (season), six *Ṛtus* a *Varṣa* (year), the sixtieth part of an ahorātra (day and night) a is called a *Ghati* (24 minutes), the sixtieth part of a Ghati is *Casak*, 1/60th part of Casak is called *Prāṇa*. Thus a day-and-night consists of 60 × 60 × 60 Prāṇas. The idea was that a healthy person generally breathed 60 × 60 × 60 times in 24 hours (day and night). Smaller subdivisions of prāṇa are also done but the principle remains the same.

Whatever the basis of these ideas, there is no doubt that the cyclic theory of time was accepted in almost all Indian philosophies. On the other hand, it would not be wrong to say that 'the principle of Mahāyuga[52] reflects the life of Indian toilers. After Kharif (autumn) crop comes winter when people remain healthy and there is abundance of food. Gradually shortage increases and finally excessive heat scorches the entire earth. The peasants have to work very hard so that the parched fields may be made ready for sowing. After that the monsoon rains fill the whole earth with water and after that the crops ripen, after some time, this cycle of weather is once again repeated. By this analogy, the logical result was that, if changes take place in a small interval of a year, similarly when the planets come together in the same line after a very long period, basic physical changes should take place in the world.'

There were no instruments for verification of the *Mahāyuga* theory, which could confirm that there was total honesty, abundance and health in *Kṛt* Yuga and if there was such a period, what was its duration and how did it come to an end. On the other hand, it is important to note that, the *Purāṇas* were written in the form of ordinary *kathās* (stories), and as such, many non-philosophic matters also found their way into them with passage of time.

Philosophic speculations about time were in abundance and the supervisor deities themselves were accepted as *Kāla* or *Mahākāla*. Thus Viṣṇu was supposed to be *Kāla*. According to *Viṣṇu Smṛti*,[53] *Kāla* was neither anyone's friend nor enemy. When the effect of *karmas* of earlier births remained no more, *Kāla* dragged man away. Krishna, believed to be an *avtāra*, claimed in *Gītā*:[55] 'I am the *Mahākāla* who destroys the *Lokas*. It is I who is the beginning, the end and the middle of Universes.' Śiva was also treated as *Kāla* or *Mahākāla* and his consort was believed to be *Kālī* or *Mahākālī*.

This style of thinking gradually led the philosophers away from natural philosophy to unknown theism, and simultaneously, faith in stars influencing human life began to grow. The same astronomy which depended on physics and dynamics became subservient to the science of stars, and instead of intellectual speculations about nature, fortune-telling became the order of the day.

II. JEWISH AND CHRISTIAN BELIEFS

Three great monotheistic religions, Judaism, Christianity and Islam, originated in west Asia. Judaism, the oldest among these, could not spread all over the world. Christianity and Islam, which came much later, kept on developing many principles of Judaism and themselves became world religions: there is hardly a country or race in which there are no believers of Christianity and Islam. These religions have occupied the human mind for a very long time.

History of Judaism

It is very difficult to say as to how old is the history of Judaism. It is conjectured that its history began 1500 to 2000 years before Christ, although the Judaists claim that they have been God's favourite people ever since the world has existed. Whatever God did was specially for their welfare. The oldest Judaists, who were called Hebrew, were the nomads of northern Arabia. Their profession was tending sheep and goats. For centuries they roamed in the wilderness of the Dajla and Furat rivers (Euphrates and Tigris) and Kanan along with their flocks. Gradually, their colonies were established near the shores of the Mediterranean Sea and, spreading into tribes, they were called Banu Israel. The most important period in the history of Banu Israel came when the Pharoah (Emperor) of Egypt planned construction of public buildings on a very large scale, but faced with a scarcity of building workers, he enslaved the Banu Israel and brought them to Egypt. They were rescued from this tyranny by Moses in about 1300 BC. Moses also belonged to Banu Israel, but an Egyptian princess had adopted him as a baby. It is said that after killing an Egyptian, he had to flee Egypt. He got refuge in Midian where he married Zippo, the daughter of Jethro. One day when he led his flock to the west side of the wilderness and came to Horeb, the mountain of God, the angel of the Lord appeared to him in a flame of fire. From the midst of a bush he saw a bush which was burning, and yet it was not consumed. God called him out of the bush and said, 'Moses, Moses, here am I. And now behold the cry of the people of Israel.' Moses had seen the oppression of Banu Israel by the Egyptians. Then God said, 'Come, I will send you to Pharaoh that you may bring forth my people, the sons of Israel, out of Egypt'. The Lord God, who gave his name as 'I am what I am' or Yahweh, gave instructions and help to Moses and finally liberated the Banu Israel from slavery. Later on, Yahweh made a promise to them which come to be known as the Covenant of Moses. According to this Covenant, it became obligatory for Banu Israel to treat Yahweh as the One God and observe all the rules commanded by him. In return, Yahweh declared Banu Israel to be His special people and promised to rehabilitate them in their paternal homeland.

The history of Banu Israel saw many ups and downs. Sometimes the Israelis had to face defeat after defeat and at other times they enjoyed the fruits of peace specially during the reigns of Solomon and David. Their views about Yahweh also kept changing. At one time they believed Him to be the Lord of the armies whose job was to help the Israelis in war. At another time they believed Him to be the Lord of the Universe, although they always considered themselves to be Yahweh's favourite folk.

The Israelis had always understood the world's history in the light of the Covenant of Moses. They believed that Yahweh created the Universe, made man the supreme creature and gave him place in the paradise for passing a life of eternal happiness. However, the first humans, Adam and Eve, disobeyed the Lord God and suffered enormous misery and sense of guilt. This was the point where human history began. Yahweh was desirous of helping man regain his lost happiness. He therefore decided to determine the direction of historical events. That is the reason why the sacred books of the Jews also called Yahweh the Lord of History.

The *Old Testament* consists of 39 books. The first five books are called *Pentateuch* (five books of Moses) or *Torah*. The *Torah* gives details of the creation of the Universe as well as the history of the Jewish people indicating that the activities of Yahweh included both creation and history as two aspects of the same action, and that the promises He made to man were really meant for Banu Israel.

For a long time Banu Israel expected good days to come but since no kingdom of the Jews could be established it occurred to them that they were perhaps not fully obedient to Yahweh. Gradually the belief grew that when disobedience and evil reached their climax, a Messiah appeared. For some time it was believed that the Messiah would only be a military leader who would humiliate the enemies of Israel. Sometimes it was felt that he would be a superhuman being who would rid the world of evil and reconstruct it. Gradually the Jews arrived at the belief that one day Yahweh would himself destroy this Universe and create a new one where honest Israelis would live happily for ever. This would be the Last Day or Yahweh's Day.

Thus in Hebrew cosmology, the law of nature, human history and the chain of time was supposed to be the same. All these began with the creation of the Universe and would end on Yahweh's Day. The intervening period was the period of Time. Whatever happened in this period was due to Yahweh's will. He alone was the originator of light and creator of darkness, the founder of safety and creator of misery. He was supposed to have framed certain broad rules and the Universe was moving accordingly. However, it was impossible for the human brain to understand these rules. Yahweh was omnipotent. He could intervene in the system of the Universe whenever He liked but He had promised the Banu Israel that no change would be made in the system before Yahweh's Day. When this day would come, was not known, but it would definitely come.

In this philosophy metaphysical problems and explanation of the observed facts were not emphasized. It was only in consonance with religions faith. From this ecclesiastical point of view, both past and future could be understood. But, according to Henri Frankfort,[3] it would be wrong to say that these views were observed or any serious thought was given to them. This solution was based on inner experience and was sufficient to satisfy those whose religion was based on obedience.

According to *Torah*, Yahweh created the earth, heaven, vegetation, animals and man in six days. The first *Book of Genesis*[4] contained a detailed description of this act: but it had no answer to the question as to whether the Universe had already existed in the form of matter and Yahweh gave it only a new form, or whether He created the Universe ex-nihilo. As a matter of fact, such a question could not occur to the Hebrew because, as John L. Mackenzie[5] said. 'The theory of creation *ex-nihilo* which is taught in today's theology needs a cosmology whose knowledge the Israelis did not have. In *Torah* the claim about the concept of creation is not that it is a key to the existence of universe. It is only a form, according to Julius Guttman,[6] by means of which man's religious understanding and God's relation becomes clear.'

Faith vs Reason

The basic assumption of Hebrew beliefs was that the omnipotent Yahweh always existed. It was He who created the Universe and His will was the cause of the Universe. Undoubtedly, every formula of faith was based on some assumption, which could not always be proved. But, on the other hand, the Greek thought was also spreading that unless something did not pass the criteria of reason it could not be accepted as true. The Jewish scholars found the solution to this problem by saying that reason itself could be obtained by faith in Yahweh. Accordingly, while some scholars interpreted the *Old Testament* word by word, other tried to link it to philosophy by their own interpretation. For example, in the first century before Christ, a Jewish scholar, Filo, composed a book entitled *Metaphor in Sacred Books*, in which he said that the language of the *Old Testament* was the language of popular tales whose philosophic ideas were hidden in the language itself.

Creation of the Universe in six days was explained by Filo thus: 'It will be very simplistic to think that the world was created in six days or that a creative task could take place in Time. The fact of the matter is that Time is nothing except the recurrence of day and night. This recurrence is produced by the revolution of the Sun above and the Earth below. The nature of Time is determined by the revolution of the sky. The Torah dictum that the world was created in six days numerically is not emphasized. In this symbolic language, it has been said that Yahweh's craftsmanship is perfect and a creation of this Universe is perfect because six is a perfect number.'

This argument totally conforms with the philosophy of the Greek mathematician Pythagoras. According to Pythagoras' dictum, every thing was a number and every number had its own hidden meaning, on the basis of which different problems could be understood. Six being the sum of its factors (i.e. $6 = 1 + 2 + 3$) it is taken as a perfect number. In the *Old Testament* also this number was used to express perfection.

Independent Existence of Time?

For many centuries the Jewish scholars did not find answers to metaphysical questions, but by the thirteenth century AD they had at least begun to ask these questions: Has Time any independent existence? Did Time exist or not before creation? Has the Universe always existed?

It was impossible for the Jewish scholars to avoid Greek philosophy in answering these questions, especially because the contemporary Muslim scholars and their predecessors were trying to combine philosophy with their own theology. As a result, the Jewish scholars agreed that the existence of the Universe depended on Yahweh's will, but it was not possible to arrive at any unified principle or belief. For example,[8] Musa Ibn Maimoon (AD 1135-1204), whose Latin name was Maimoondis, accepted Aristotelian theory that Time was only a number on the basis of which motion from preceding to succeeding was understood. Thus Time had no existence of its own; it was not even motion, because motion itself was an event, which occurred with material things or bodies. Therefore, Time ought to be understood as an event of events. It depended on two facts—past or future; while past had passed away, future had no existence as yet. As regards the present, it only existed between the two. In this sense, Time could be called 'semi-real'.

Aristotle believed that the nature of Time itself provided rules for the Universe without beginning and end. Ibn Maimoon said that this assumption was wrong. Time came into existence at the time of creation of the Universe. Before that, there was only Yahweh's timeless eternity. Yahweh alone was absolute, non-material and free from motion. Ibn Maimoon also asserted that, even if it was agreed that the Universe had always existed, Yahweh's timelessness was not affected. Only His will was important. Creation might have occurred *ex-nihilo*, yet this was dependent only on Yahweh's will.

Hasadi Kriskas' Opinion

Contrary to Ibn Maimoon, Hasadi Kriskas believed that Time was not an event of movement. In fact it was 'the continuation or duration of a conscious brain'. In other words, during an interval between two instants, how much movement took place determined the measure or quantity of Time. Thus Time did not depend on motion, because it existed as a duration. Besides, being the duration of the mind's activity, it did not exist outside the brain. This led Kriskas to infer that Time had no 'semi-real' existence. Time was connected with duration and duration was related to the brain, not the body or material. Therefore, Time could be associated with Yahweh who was absolutely non-material. In this sense, Time had always existed, even before Creation. Before Creation, it existed in the never ending consciousness of Yahweh.

This dogma was developed[9] by another Jewish scholar who asserted that 'real time' had not existed before Creation. When the sun, the moon and other planets had already been created, then motion also began and only then did it became possible to measure duration or interval. Therefore, the existence of 'real time' ought to be taken only after that.

Evolution of the Idea of Space

Similar ideas could be found in other Jewish beliefs. Initially the Hebrew word *Maqum* (*Moqam* in Arabic) was used as a synonyms for a holy or sacred place, but as time passed it was taken to be a title of Yahweh. The *Old Testament*[10] said: 'Yahweh has always been our abode'. It was inferred from this that the Universe was not the abode of Yahweh. Max Jammer was of the view that this was not only a metaphor but the 'fruit of a long period of theological thinking'.[11] The basis of this belief was that Yahweh was present everywhere, that is, He was Omnipresent. For example, according to the *Old Testament,*[12] 'The same Lord is above the skies and He is below the Earth. There is no one else other than Him.' From this concept it would be inferred that God was inherent everywhere, but the Jewish scholars formed the view that Yahweh himself was Maqum or Space. In the first century before Christ, Philo explained the idea further: that things were situated inside Space and because Yahweh had enveloped all things and no other thing could take Him inside, therefore, Yahweh would be His own Space.

The ideas of Musa Ibn Maimoom accepted the Aristotelian view of space. Accordingly, he made a distinction between a 'particular place' and a 'general space': the former was the space occupied by a separate body while the latter enveloped all bodies, including the seven heavens. Because the Universe itself was limited, general space was also limited. However, calling Yahweh as Maqum did not mean that He was general space or limited. In his book, *Dalalat-ul-Haratiyeen*[13] (Guide to the Perplexed) Maimoon asserted that every name or epithet of God was associated with some particular action of His and as the *Book of Zechariah* said, on the Day of the Lord, 'the Lord will be One and His name One'.[14] The *Old Testament* had also stated that before creation 'He was and his One Name'. All this goes to show that all the names of God were based on different aspects of creation. Only Yahweh was associated with His Existence, no other attribute. It was not possible for everyone to understand His Existence; and therefore, this particular name of the Lord could be taken by only some chosen people on special occasions. But people in general could remember Him by the name of Maqum, because this word indicated the rank of His Existence.

Just as, in daily conversation, it is said that 'so and so has taken the place of his father in learning', which really means that 'so and so holds the same rank in his learning, as his father did', similarly, calling Yahweh as Maqum, or his own place, simply means that no rank was similar to it. Moreover, Maimoonides Hasadi Kriskas claimed that 'this Universe is His form'.

Beside these explanations, to prove that Yahweh was Maqum, an argument was advanced from a particular branch of arithmetic. The early Greeks believed that the qualities of anything could be determined by its name. In this branch of arithmetic, every letter of the alphabet has its particular value. For example, M = 40, Q = 100, U = 6 and M = 40. Thus, 40 + 100 + 6 + 40 = 186 represents MQUM or Maqum. On the other hand, Y = 10, H = 5, W = 6 and H = 5. So 10 × 10 + 5 × 5 + 6 × 6 + 5 × 5 = 186 representing YHWH or Yahweh. From this the Jewish scholars jumped to the conclusion that Yahweh and Maqum were the same. It is quite obvious that this so-called argument does not hold water because while the numerical values of the letters of MQUM are added simply, those of YHWH are added after squaring them up. Ordinarily[15] the arithmetical value of YHWH would be 26 and that of MQUM would be 186 and this would have meant that the former was included within the latter. Since this result would have been against the theological belief of the Israelis, which would have ended God's spacelessness, the Jewish scholars did not hesitate to change the rules of the game to prove a particular theological principle.

Space and Christian Thought

The roots of Christian religion are connected to Jesus, son of Mary, who was herself born in a Jewish family. Jesus said[16] 'Think not that I have come to abolish the laws and prophesies. I have come not to abolish them but to fulfil them. For truly, I say to you, till heaven and earth pass away, not an iota, not a dot, will pass from the law until all is accomplished.' While preaching in synagogues he reminded the people of the foretelling of the Prophets. His message was very simple: 'Lord God only is the owner of the Earth and Heavens. His kingdom is at hand and I have come to complete it.' This was the time when the people of western Asia were oppressed under the yoke of the Roman Empire. This message gave hope of better days to the oppressed people. So the idea spread that Jesus was the same Messiah whose coming had been foretold by the Jewish Prophets, but Roman rulers and the rich Jews declared Jesus to be a rebel and, according to J.D. Bernal,[17] 'Jesus had the same fate that revolutionaries have.'

When God's kingdom was not established and Jesus was crucified, his followers were very much disappointed but they consoled themselves and hoped that this system of tyranny would soon come to an end. It was postponed for a short while till the return of Jesus. So they waited for the second coming of Jesus in this very world to correct the system. But gradually, when even well-to-do people began to accept Christianity, then neo-Platonic views also began to enter this religion. According to neo-Platonism, religion belongs to 'another world'. Therefore the Christians concluded that on the second coming of Jesus, this world will be destroyed. A final judgement will take place and a system as promised in *Pentuta* and *Psalms of David* will be established. From here the concept of 'life after death' entered Christianity. Thus, Christianity not only introduced new philosophy but for quite sometime conscious attempts were made to break from Judaism and establish Christianity as a new religion. Thus, in the end, all the 39 books of the *Old Testament* and 27 books of the *New Testament* were added to the Christian faith. Thus, in Judaism only the *Old Testament* was believed to be the heavenly book, but the Bible or the holy book of Christians contains both the *Old Testament* and the *New Testament.*

The *New Testament* claimed that God loves human beings, so he sent his son in the form of Jesus who died and came to life again. Thus he broke the wall separating man and God and redeemed man. Due to the first disobedience of Adam, man's eternal life was taken away as punishment, but Jesus once again enabled man to meet God and eternity returned to him as a prize. In this sense, according to Marslo Kravery, 'Jesus should be taken as second Adam. Adam threw man in the rigmarole of sin and death and Jesus got redemption for man.'

In the early period of Christianity, the message of hope of Jesus was sufficient for theological needs. The other problems were also solved on the basis of religion for which the Jewish traditions served the purpose. The only difference was that, along with Yahweh or God, Jesus was also made a partner. Besides this, there was no change in cosmology. For example, the *New Testament* claimed[18] 'For us, there is only One God or Father and all things are from Him and we all are for Him and only One Lord Jesus Christ through whom all things appeared and we all are through Him.' Besides, certain Greek philosophies that reinforced the belief in the other world were also gradually accepted, but no need for experimentation or observational science was felt. This was the reason why the Christian view of Space remained the same for centuries as was established in classical Judaism. The Jewish belief that God was Maqum and what the *New Testament* said:[19] 'In Him, we live, move and exist', were more or less similar in nature.

Although Aristotle's and Plato's theories were criticized and explained away, yet no new metaphysical principle about space could be established. How deep were the roots of these beliefs could be estimated from the writings of Nicholas Cuzanas (AD 1401-64), who was counted amongst important mathematicians. For 30 years he was a Christian minister and was entrusted in 1440 with the responsibility of establishing theological unity between various sects of Christianity. He admitted that the manifestation of nature cannot at all be understood on the basis of mathematics. In his writing[20] *Scholarly Ignorance*, he asserted that there was no circumference of the Universe. If it had any centre and circumference, then by the same token it would have a beginning and an end. Accordingly, the Universe would have been bounded in relation to something else and there would have been some other thing beyond it and there would have been space. But all this is not there because it was not possible to delimit within a material centre and a circumference. Thus, our minds did not comprehend the universal. This would mean understanding God who was the centre and circumference of the Universe.

This formula of Nicholas Cuzanas was not only a metaphor. In elaborating it, he said that centre[21] was the point which was at equal distance from every point on the circumference, but no circumference whether it be the earth or heavenly spheres was completely circular (round). Therefore, no circumference could have a centre. Moreover, if anyone were to stand at any place in the sky, he would feel that he himself was the centre of the Universe. In reality, only God was the One who was at equal distance from everything. He alone was at 'unbounded distance' and, therefore, the centre of the Universe. He alone was the centre of everything—the earth, different levels of heaven, and the unbounded circumference of everything else.

This argument of Nicholas Cuzanas did not stand the test of mathematics, although geometric terminology was elaborately used. For instance, there was no proof for the assumption that God was at equal distance from every thing. Besides, he believed that the centre and the circumference were the same. According to Max Jammer,[23] this was sheer nonsense on the basis of physical principles. In spite of these fallacies, this view had great importance in scientific thought and Christian belief, because it was a sample of ideas that allowed all physical problems to be solved on the basis of mixed philosophy.

By the seventeenth century in Europe, the importance of science began to grow and religious matters and old style theological arguments could not serve the purpose. Therefore, great emphasis was laid on the study of science in Britain so that 'God's craftsmanship could be understood better and His existence could be proved on scientific basis'. Physics was given great importance in religious circles as natural philosophy. For example, Moor (AD 1614-87) on the basis of his study of Time and Space presented the hypothesis that Time was no mental object. It was absolute, its existence was real. It had no beginning and no end. It was infinite and unlimited, but it was not material. These very qualities were those of God as well. God and Space both had the quality of essential existence. Moor therefore inferred that both were the same, although according to Alexander Koyre,[24] it could also be inferred that 'the material universe is itself unlimited. It has no beginning and no end. Then no need would have been felt of God's creative action and finally no need for believing in the existence of God itself.'

Moor's ideas left a deep impression on the thought of British thinkers. It is generally believed that his thoughts were the basis of Newton's scientific theories. A friend and colleague of Newton, Joseph Raphson (AD 1648-1716) published his mathematical treatise entitled *Analysis of General Equation and Solution of Algebraic Equation.* In its appendix, he discussed the question of 'Space or Unbounded Infinite' being without beginning or end. He tried to prove Moor's ideas on a mathematical basis. He advanced the argument that if the Universe was tightly filled with matter, any motion in straight line would be impossible and it would be very difficult even in circles. However, the fact that every type of motion did take place proved that vacuum or 'vacant space' existed inside this very expanse, which allowed motion. This expanse was itself without body, without movement. It was non-material and absolute.

Raphson further argued that it was the quality of matter to occupy space and to move; and in this sense, matter was limited and also imperfect because its form and place could change. Besides, every material thing could be split into parts. There would be some distance between those pieces, although it would be very small. Thus, matter could be called an 'expanded thing'. If there were no space, expansion would not take place nor would things be able to accept different shapes. If all things were compressed so that no distance remained between them, the expanse of the Universe would be further narrowed. But Space was that great expanse that the biggest arrangement of limited bodies was like being inside it. Its expanse and nature could not be comprehended by the human brain. Inside it 'here, there, between, etc. are completely lost. This unlimited existence is a unique one and absolute perfection in its nature'. By his analysis of the qualities of Time, Raphson inferred that everything which was absolute, infinite, unbounded and eternally existed would inevitably be the manifestation of the existence of the 'first cause'. Henry Moor had attempted to prove that God and Space were one and the same considering their common attributes but according to Alexander Koyre:[25] 'Raphson on the one hand claimed that unboundedness was perfection and on the other hand proved that expanse was perfect.' It thus became inevitable to infer that Space was an attribute of God on the basis of logic and metaphysics.

Christian Views about Time

The Christian concepts about Time were also basically theological. In fact no difficult theory about Time was presented in the *New Testament.* The only emphasis was on God's favour being manifested through Time and Jesus was associated with this action. Man's redemption was a continuous action of Time, which joined past, present and future in a straight line. This line did not change direction anywhere and remained continuous. According to Jesus, this line was divided in three parts: (i) before Creation; (ii) between Creation and the Last Day; and (iii) after the Last Day. The *Old Testament* did not present a clear picture and the Last Day also appeared to be in a remote future. But in the *New Testament,* time, pre-beginning and eternity were accepted as one and associated with the life of Jesus. For example, it was said[26] in the *New Testament*: 'Jesus did exist before Creation but he was manifested during the interval between Creation and the Last Day.' In this period before the Last Day also Jesus was eternal; only he was the 'beginning and end', first and last. 'It is he who is yesterday, today and eternity.'

In this form the importance of the pre-Creation period was understood, although Adam had not yet come into existence. The picture of the Last Day also became clear. Now there was no waiting for any unknown messiah in the remote future. The messiah had already appeared, he had passed some days amongst men in the form of Jesus, son of Mary and, after the Crucifixtion, he was still alive and would soon return.

On the basis of these beliefs the chain of time was called the Line of Redemption or the Line of Jesus. Every point of this Line indicated God's craftsmanship and could be understood on the basis of the life of Jesus. Every instant was an important moment of universal history and no moment came twice. In this continuous collection, every event had some meaning and through it, the past events were connected with the coming events. However, no one could know about these moments because God Himself determined them just as He determined the weather. This belief might not be in conformity with logical deduction, but there was no theological flaw in it . According to Oscar Cullman:[27] 'If we watch beliefs of early Christians about Time, then we must completely free ourselves from all philosophic concepts about Time and Eternity'.

An important question associated with Time was whether the world was created or not and, if created, when and in what interval. For a long time Christian scholars debated this question and were even divided in different sects. About a hundred years ago, over 140 views had been expressed, but all agreed that the world was created and at some definite time. The great Christian scholar, St Thomas Acquinas[28] (AD 1226-74), devoted a full discussion to this question, and finally claimed that through logical argumentation it could not be proved that this Universe had not always existed; but 'woe on them who try to prove that matter was created in Time'. In fact, according to St Aquinas, Creation was a miracle which could be comprehended on the basis of logic. The belief in the Creation of the Universe in Time was an essential part of religious faith.

It was claimed that God created the Universe in six days and on the seventh day took rest. For a long time discussion continued to find out the meaning of 'day'. One explanation was that 'day' did not mean 24 hours but a thousand solar years. In *Psalms of David*[29] it was said that 'in Thine eyes a thousand years are like yesterday's day and period of night which passed'. The same was repeated in the *New Testament*:[30] 'Before the Lord a Day is equal to a thousand years'. With this explanation, the life of the Universe was calculated and it was conjectured that it was not older than six or seven thousand years. However in the nineteenth century, Charles Lyall published his *Principles of Geology*, which presented the view based on geological research that the Universe was indeed very very old and more than many hundred thousand years had passed since man appeared in his present form. The Christian scholars then explained this by saying that 'day' did not mean a thousand years only. It indicated a geological period which consisted of many hundred million years. Creation did not take place at any specific moment. This was God's action whose continuity was never broken The very existence of the Universe was proof that this action was still continuing, but God himself would discontinue it in one day. In AD 1877, a Canadian scholar, W. Dawson, made a comparison of the geological theory and Christian faith and claimed that they differed only in technical terms and words, but indicated the same matter.

From this linear theory of Time arose another vital question: When will Time end? The companions of Jesus believed that the Last Day would come during his life time itself. In the beginning of the third century AD Julius Africanos[31] calculated that Adam was born in 5499 BC. Thus, $5^1/_2$ days of Creation had already passed when Jesus came. The sixth day would be competed in AD 500. Only then would Jesus return, and after a government of 1000 years the world would come to an end. Similar dates kept on passing, but people believed that the kingdom of Jesus was soon to come. Christian wandering minstrels of the middle ages gathered people on the slogan that the end of Time was near and, for the downtrodden people and the faithful, a system of complete justice would be established soon. Stephen Tolman and Johan Goodfield were of the view that this was the main reason for the enthusiasm of the Christian masses during the Crusades.[32] Thousands of men marching towards the Holy Land believed that the war against the infidels (Muslims) was a prelude to the Messiah's coming. The crowd consisted of a large number of peasants and unemployed urban people. The priests and the worldly rulers were ashamed of their tattered clothes. They could not stop them from participating in the Holy War. However, they had a deep-rooted hatred against them, as they considered movements a great danger to their own authority.

When in the sixteenth century Martin Luther began his religious reform movement, he calculated that Creation took place in 400 BC and the world's total life span was only six days. Therefore, it should come to an end in AD 2000. However, moral degradation and evil deeds having increased tremendously, God might not wait that long. Later, Johann Kepler (AD 1571-1630) inferred on the basis of calculations of solar eclipses that there was a difference of four years in Christ's date of birth, and that the world came into existence in 4004 BC on Sunday, 23 October, at 9.30 p.m. On this basis, Archbishop Usher, of Ireland, inferred that the Last Day would begin on 23 October 1996 before 9.30 pm. Bishop Usher's date was taken as the standard in the calendar of the British and Anglican Church. Some other sects believed that the world would end in 1968. Jehovah's Witnesses claimed that if the world was not destroyed in 1975 some sort of destruction would definitely begin. In this connection, about 100 years ago, the French scholar Flamarion gave the warning that 'The result of such speculation is diverted away from the healthy study of astronomy. The only point which comes out is that if science gives even a millimeter of space, it itself loses its path.'

As the basis of these beliefs was about the beginning and end of Time, the practical question was how man would attain redemption. These views served the theological needs but no particular attention was given to theoretical speculation. Even then Christian scholars had to face philosophical and metaphysical problems. In this connection St Augustine[33] (AD 300-54) laid down the foundation of explaining and establishing religious problems by combining philosophy, metaphysics and matters of daily experience. During the Middle Ages and Reformation, no other Christian thinkers than St Augustine left such a deep impression on Christian thought. His dictum was: 'first believe, then understand'. He explained every problem starting from some statement in the Holy Bible. He argued that there was bound to be some first instant. Even if we accepted that there was no such instant, we could not say that Time was without beginning and end. God created Heaven and Earth. Similarly, Time had also been created and came into existence by 'God's will'. Therefore, it was wrong to believe that Time existed before the beginning of Creation. Besides, Time had past, present and future, but God was omnipresent and had neither past nor future. Then where was the question of God existing or not existing before Time?

St Augustine advanced the view that Time was the activity of the spirit by means of which man could measure the 'quantity of motion'. When any event took place its picture was formed in the human brain. Later, it changed into words. When man recalled the past, he saw the associated picture from his 'mind's eye', although the actual event had become non-existent. Even then a man could describe events of the past in reality. He did not present those events but only those words that had emanated from the associated pictures and were present in the mind for ever. Generally, Time was calculated on the basis of revolutions of the moon and sun. But Time did not depend on the motion of the heavenly bodies. For example, if the movement of the sun became fast or slow, even then the period of one complete revolution would be called day and night, although these periods would be equal. Movement itself was measured by means of Time, but how could we measure Time? Spatial expanse could be measured in terms of small spatial expanse. For example, the height of a wall could be calculated on the basis of the length of the hand, but there was no such measure for Time. Sound was also a movement as long as it emanated but it could not be correctly measured, and after it stopped its existence stopped, too. Therefore, it could be said that there were some time-intervals in the human mind which could measure Time on the same scale. From all this St Augustine arrived at the conclusion that the activity of the spirit was an absolute measure which was independent of the laws of motion. Thus, Time could be understood as an 'extension' of the spirit. Theologically, this meant that life was a continuous expansion or deviation, because it was Time which was the basis of change in continuity in the Universe. Whatever the human spirit came to know was due to the change of Time, and by remaining in this world it became subject to expansion and disturbance. Therefore, man should try to raise himself to a higher level, separating himself from this expansion, and look towards God's favour.

Comparison of Scientific and Theological Views about Creation (according to Dawson)

According to the Holy Bible		*According to Geology*	
Day		Period	
First	Vapours produced by mist covered the Earth; light created	First	Vaporous matter thickened breaking the hot nebula into pieces, which began to fall forming celestial bodies
Second	Earth was covered with water and atmosphere came into existence	Second	First universal ocean and water appeared and atmospheric balance was established
Third	Dry earth appeared and vegetation grew.	Third	Earth came into being and from it gradually rocks began to be formed
Fourth	Arrangement of solar system completed	Fourth	Lifeless rocks took different shapes; arrangement of present weather appeared; the stage before formation of mountains, etc began
Fifth	Invertebrate animals and fish came first, followed by huge crawling beasts and birds	Fifth	Vegetation appeared on Earth; invertebrate animals and fish appeared; gradually beasts crawling on earth came into being
Sixth	Mammals, human beings and other animals appeared	Sixth	Mammals and finally man came into existence
Seventh	Work of creation ended; Adam descended from Paradise	Seventh	Epoch of man
Eighth	End on the Last Day and emancipation; new Heaven and new Earth come into existence for pious men; day of rest.	Eight	No end in sight

III. ISLAMIC BELIEFS

Prophet Mohammed was born in AD 571 in the city Mecca in the central Arabian peninsula. In those days the city was the most important commercial and religious centre of Arabia. The holy place, Kaaba or Masjid-ul-Haram, originally built by Abraham, was also situated in this city. Christianity could not become popular in that peninsula but Judaism had already been well established. With the passage of time people began to forsake belief in monotheism and each tribe had its own gods and goddesses. Idolatry had permeated the life of the Arabs so much that each day of the year was fixed for some particular idol in Kaaba. Besides, *Dahr* (Time) was also accepted as a god. It was believed that *Dahr* had always existed and would always remain. *Dahr* gave birth and death to man; it was the master of destiny. Mohammed had intense hatred of idolatry. At 40 years of age, he declared his prophethood and started his campaign for eradication of idolatry, preaching the message of monotheism to all humanity. In this mission he had to face all sorts of trouble. For eight years he had to live in exile but in his lifetime itself a large population of the Arabian peninsula had embraced Islam. The Prophet died in AD 632 . Within five years his followers defeated the armies of the empires of Iran, Rome and Byzantine. By the eighth century AD the Islamic empire spread from central Asia to Andalus (Spain) and western Africa. The empire was subsequently destroyed as a result of despotic rulers, but Islam occupies the hearts and minds of millions of people even today. This success was a marvellous feat in human history. The main factor for the popularity of Islam was the absence of any scope for social inequality. The slogan of universal brotherhood was very attractive. Religious practices were simple but demanded strict observance. Theology consisted of simple monotheism and generated hope in a real 'paradise' for the faithful. All the earlier prophets mentioned in the holy Jewish and Christian books were sent by God. Mohammed was the last of the line and Quran was revealed to him in which God's words were presented in the most perfect form.

Quran did not present any theological proof for the existence of Allah, His nature or attributes. The message was addressed to those who believed in the Ghaib (Unseen). To explain the relation between the Universe and *Tauheed* (monotheism) it was said in Sura-e-Rad (The Thunder):[1]

> Allah, it is who raised up the heavens without visible support, then mounted the Throne and compelled the sun and the moon to be of service, each runneth into an appointed term. He ordereth the course; He detaileth the revelations, that happily ye may be certain of the meeting with your Lord.
>
> And He it is who spread out the earth and placed therein firm hills and flowing streams, and of all fruits he placed therein two spouses (male and female). He covereth the night and day. Lo! here in verily are portents for people who take thought.'

These views led more or less to the same articles of faith which were given in the *Old Testament* (i.e. God was omnipotent). According to Quran, this Universe was created only once and it would be destroyed once only. Then once again new heavens, new earth would be formed which would always remain. Thus, Quran accepted the linear theory of Time that the period of the Universe began 'sometime' and would end 'sometime', and it would not come into existence again. The only difference was that the Jewish faith did not require any 'natural laws' but, according to Quran, Allah had not left the Universe without order. He was the 'Organizer of Matters'. He had given a particular arrangement to the celestial bodies. For example, in Sura Yasin,[2] it was said: 'The sun runneth on unto a resting-place for him. That is the measuring of the Mighty, the Wise. . . And for the moon We have appointed mansions till she return like an old shrivelled palm-leaf. . . It is not for the sun to overtake the moon, nor doth the night outstrip the day. They float each in an orbit.'

Mutazilites—the Free Thinkers

In the initial stage of Islam it was believed that Quran was adequate for solution of all problems, But when the Islamic empire expanded, the rulers began to face multifarious and complicated problems—legal, moral, political, social, military and administrative. Hence, many schools of thought sprang up, but not without help from Quran and the Prophet's life. One such school, called the Mutazilites, was founded by Wasil bin Ata (AD 699-749). The Mutazilites believed that the Universe was a purposeful organization in which one had to pass through intermediary purposes to arrive at the final purpose. These intermediary purposes were called *Asbab* (causes) which produced a practical effect of the immediate results. Abul Hudhail 'Allaf', an important Mutazilite, was supposed to be the founder of speculative theology. He introduced the principle of *Jawhar* (atom) and *Arḍ* (accident) in theological discussions. According to this principle everything other than Allah was a combination of *Jawhar* (atom) and continuously created *Arāḍ* (plural of *Arḍ*, i.e. accidents) and associates them with bodies or space. Still, some Arāḍ like Allah's wish and Time did not require any body. These views of Abul Hudhail, which were purely physical, were used to prove the correctness of theological principles.

It would be wrong to think,[3] that the Mutazilites were complete free thinkers. They had introduced some Greek methods in their argumentation, but generally they advanced their proofs from the Holy Quran, often supported by incidents from the life of the Prophet and commentaries on the Holy Quran. Gradually, however, differences sprang up among the Mutazilites on the fundamentals during discussions. And in the tenth century AD, a prominent Mutazilite scholar Abul Hasan Ibn Ismail Al-Ashari (AD 873-936) founded a new school of thought. Al-Ashari believed that Allah was totally free from physical laws or the principles of cause and effect. In the Universe, creation also takes place instantly (i.e. every *Aān* or moment) in which Allah renews the Arāḍ (accidents). From this it followed that for obtaining every separate object (*G͟hāyet*) Allah had arranged separate chains of events, but no event was the cause of its following event. The first and the last cause was Allah himself. He was Musabbebul Asbab (Ordainer of Causes). He was the first and the last link, and all necessary links followed from Him.

Asharite Atomic Theory

Later on by the introduction of Jawhar and Arāḍ, the Asharites built up an entire school of theology based on the so-called atomic theory. The attitude of the Asharites towards earlier such literature depended on the political and administrative requirements of the kingdom, because Greek and other non-Islamic thoughts were quoted in them. During the reign of Mutamad (AD 870-892), it was felt that the Asharite and Mutazilite literature was becoming the source of spreading heresy. Therefore it became a crime to sell such literature. D.S. Margoliuth[4] felt that when Mahmud Ghaznavi (AD 970-1030) plundered the city of Ray he burnt all such books in the city library, as a result of which the standard classical literature was rarely available. About 200 years later, Abu Imran Musa ibn Maimoon ibn Abdullah (1135-1204), called Maimundees, wrote *Dhalat-ul-Hairatiyeen*[5] (Guide to the Perplexed), in which the atomic theory of Asharites was dealt with in detail. Much later, in AD 1885, a German scholar[6] Moritz Guttman presented a brief summary of the atomic theory from *Dhalat-ul-Hairatiyeen.*

According to the Asharite theory, the Universe and everything in it was a collection of very minor particles. These particles were so small that they could not be further subdivided. They were called 'al-juz al-ladi la yatajazzo' (a part which could not be subdivided) or Jawhar-al-Fard (individual Jawhar) or simply Jawhar. All Jawhars were completely uniform and simple. Separately, each Jawhar was like a point in which there was no expansion or quantity other than *Tahayyuz* (position). When many Jawhars combined together a *Jism* (body) was formed, which could take dimensional space quality (i.e. length, breadth and height developed). When the Jawhars separated the body came to an end. Between two Jawhars there was some empty space, called *Khala* or vacuum. Two Jawhars met or separated due to movements inside the vacuum. If there was no vacuum such a movement was not possible. So, when the Jawhars met, their separate existence did not come to an end. In Asharite theory it was believed that Jawhars could not take each other's place. They only conglomerated or joined together.

This view led to the atomic theory of the present time. Aristotle believed that there was a special relationship between Time, Space and Motion. However, as pointed out by Moritz Guttman,[7] in spite of their dislike for Aristotelian philosophy Asharites argued on the same basis that if anything moving with uniform speed covered some distance in a moment then it would cover half the distance in half of the moment. Similarly, in the fourth, eighth, sixteenth and thirty-second part of the moment it would cover, respectively, a fourth, eighth, sixteenth and thirty-second part of the distance. If it is accepted that every small moment could be divided into two parts, then one has to believe that every small portion of distance could also be divided into two. But distance depends on space atoms. Therefore, some distance would be so small that its further subdivision would not be possible. Thus, this very assumption that every portion of moment could be subdivided into two was wrong. Accordingly, Time could not be subdivided *ad infinitum.* Similar to space-atoms, there was *Zamani Jawhar* (time-atom), called *Aān* (instant). Just as by a conglomeration of space-atoms bodies were formed, which were situated in space, similarly Time was also a collection of *Anat* (plural of *Aān,* i.e. instants). None of the two was continuous. There being vacuum between space-atoms, Time should be understood as a sort of dotted line on which instants of Anat were spread out like points, with some open space between two points. The Anat had no quantitative property, but they did have relative positions.

Some peculiarities may get associated with Jawhar through Arāḍ (accidents). Jawhar could be treated as Matter in the sense that it was the conveyer of Arāḍ. Neither could any Jawhar be free from Arāḍ, nor Arāḍ be separated from Jawhar. The difference in bodies were produced only due to Arāḍ; for example, ice had whiteness because in every Jawhar of it the Arḍ of whiteness was associated. Jawhars were uncountable but Arāḍ were very limited. The most important thing about Arāḍ was their *Be-Sabati* (ephemerality). Jawhars did stay for a while but Arāḍ did not stay for more than an instant. They were continuously formed and annihilated by an act of Allah. This process was called *Tajdid* (renewal of Arāḍ). This chain of renewal would be continued by Allah as long as He wished. When he would terminate this process, Jawhar would also be annihilated. Thus, for maintaining the Universe, He had to continuously create Arāḍ and Jawhars. Allah created a new atomic universe in each atomic time. Creation was thus a continuous process which went on every instant. A body in motion had in all its Jawhars the Arḍ of *Harkat* (motion) continuously renewed.

Although existence of the Universe was inevitable, it depended only on Allah's will. He could make it as he liked and remake it in future as he wished. This later Universe could be entirely different and its laws could be completely opposite of natural laws.

It was quite obvious that the Asharite theory had no relation with physics; at the most it was a sort of intellectual conjecture, whose basis was theological. Here experience, experiment and evidence of the senses were secondary. The Asharite scholars asserted that whatever was found through observation and experience was not free from error. For example, according to these scholars, it was possible to know Allah through *Aql* (intellect) without the aid of verses from the Holy Quran. They started with the assumption that Allah existed. He created the Universe at some time and it was He who would annihilate it. They had no doubt about this basic assumption or article of faith. Only a further 'intellectual proof' was required. In this quest, the atomic theory came handy. Here there was no emphasis on 'cause and effect' as every small or big thing in the Universe had a beginning and an end. Thus, Aql (intellect) itself said that there must be someone who begins and ends. He Himself had no beginning or end neither in Time, nor in Space, nor in Motion. He himself began and ended Time, Space, Motion, etc. Being the Omnipotent, Allah was not bound by any principle of cause and effect. Thus, many problems of faith were resolved and the principles of Quran[8] were confirmed, Allah being the creator of all things, guardian of all beings, and the keeper of the keys to the Heavens and Earth, and those who disbelieved the revelations of Allah were the losers.

Origin of Asharite Atomic Theory

Such views had already been established in Ionia (Greece) about 500 BC a thousand years before Islam, and there were quite a few similarities between the two views. According to the Greek theory, atom was that part of matter which could not be further subdivided. The same was the definition of Jawhar. Both theories believed that a thing (*shai*) was formed when atoms conglomerated and when the conglomeration broke the thing was destroyed. However, there were some fundamental differences between the two views. The Greek believed that atoms had always existed and would always exist. Their existence did not depend on anyone. On the contrary, according to the Asharite atomic theory, Jawhar (atom) came into existence every instant and it was dependent on continuous divine creation for its continued existence. Besides, the Greek thought that all atoms were in continuous motion and separated or combined only due to need or chance, but, according to the Asharites, all motion, chain of events, existence depended only on Allah, and there was no intervention from any one or thing. Thus, in the two views, there was less similarity but more difference. And as such, it would be wrong to say that the Asharite atomic theory was a product or derivative of the Greek atomic theory.

About seventy years ago a Scottish scholar, D.B. MacDonald,[9] expressed the view that the roots of Islamic atomic theory would have to be searched for in India, because all Islamic ideas could not be said to be the product of Greek philosophy. Recently, Majid Fakhry[10] also arrived at the same conclusion, that the ephemerality of Jawhar and Arāḍ indicates Indian influence. About the time the Greek atomic theory was being evolved various schools of Indian thinkers had begun to believe that everything in this Universe was a conglomeration of atoms. It was on the basis of these views that philosophies like Nyāya, Vaiśeṣika, Vaibhāṣika, Swatāntrika and Jaina Darśana developed. Vaibhāṣika and Swatāntrik philosophies were associated with Buddhism. Evolved during the second century, both the philosophies had presumed that *Paramāṇu* (atom) was the minute shape of *Rup* (matter) and any particle smaller than it could not even be imagined. Paramāṇus neither touch each other nor coalesce into each other. There is some empty space between them and their conglomeration takes place every moment. When Paramāṇus conglomerate the unit formed was called *Aṇu* (element). All bodies were made up of Aṇus. According to Vaibhāṣika, Paramāṇus separated immediately after combining. Their span of existence was just as long as lightning flashes. Things remained only for four moments: (i) the moment of appearance; (ii) the moment of existence; (iii) the moment of decay; and (iv) the end.

Swatāntrik philosophy believed in *Kṣanikvāda* or instantism. In its view everything remained or fell in one instant only, and the very next instant its exact copy appeared in its place. These views were very similar to Asharite theory, although there is no mention of the involvement of any non-material being in this process. Still, it stands to reason that Muslim thinkers had known for long about *Aqaide-Ahle Hind* (Faith of Indians) written by Yahya Barmaki and many Sanskrit books translated into Arabic. It should be noted that whenever Muslim thinkers got any intellectual property they did not hesitate in taking it, but always used it for their theological requirements by giving their own interpretation. However the question as to how the theories of Vaibhāṣika and Swatāntrika philosophies reached Muslim thinkers and through what media needs to be explored.

Opposition to Atomic Theory

The atomic theory was opposed by two circles of Muslim scholars—the Fundamentalists and the Falasifa. Amongst the fundamentalists the most important was Ain Muhammad Ali ibn-e Hazm (AD 994-1064). He was against 'intervention of intellect' in religion and speculation to understand the attributes of Allah.. He believed that only (a) Quran, i.e. Allah's Book, (b) Hadith or the Sayings of the Prophet, and the model of his practical life, and (c) *Ijma,* (i.e. the unanimous opinion of the Prophet's companions, could be the guides in matters theological. Other means led to the path against religion. The fundamentalists did not approve of the atomic theory of Asharites but did believe in continuous creation. According to them, the Universe was a solid globe which contained the Earth and the Seven Heavens, but there was no open space or vacuum. Whatever was under the sky was a collection of bodies. These bodies themselves were Jawhar which could not be called atom. Human soul was also Jawhar or a body which separated from the main body at death. Arāḍ could be associated with Jawhar only. Allah created Jawhar and Arāḍ continuously but He was not bound by any law. So, before creating new Arāḍ He did not annihilate further Arāḍ. He did retain an atom as long as He liked and could make atoms coalesce. Motion and rest were also Arāḍ. One of the Arāḍ remained associated with every Jawhar. When air was pressed a body found a place or motion, which proves non-existence of vacuum. Similarly, as material bodies were not composed of atoms, the existence of time-atoms could not be believed. Ibn Hazm did not advance any alternate theory while explaining the idea of 'continuous creation. He only emphasized that, for theological problems, old trends or non-theological sources like philosophy, speculation and unanimous opinion of Muslims were totally unacceptable. This applied to all aspects of individual life—political, individual, social, legal or academic.

Ibn-e Hazm did not meet with much success because the Asharite theory was increasing in popularity. However, in the fourteenth century AD Ibn Taimiya (AD 1261-1327) of Syria and in the eighteenth century Mohammed ibn Abdul Wahhab (1703-92) of Najd (central Arabia, home of the present Saudi Arabian kings) tried to enforce these principles strictly. Even today, Ikhawan al Muslimeen, a similar political body, has been trying to enforce these principles.

The atomic theory of Asharites was also opposed by another class of Muslim thinkers.[11] called the Falasifa. Their opposition was on a different ground. They had complete faith in Islamic doctrines, but, simultaneously, they believed that theological anomalies could be resolved on the basis of reason. As Greek wisdom, according to them, was the best product of the human brain, it might be possible to arrive at the truth by means of Greek philosophy. Abu Yusuf bin Yaqub bin Ishaq bin As-Sabbah Alkindi (AD 800-72) was the first to apply such logic for confirming religious dogmas regarding God's existence, Creation *ex-nihilo,* and annihilation of the world. Later, Abu Nasr Mohammed bin Mohammed bin Tarkhan bin Uzlugh Alfarabi (AD 870-950) advanced this movement further, but in fact the climax was reached in the works of Ibn Sina (AD 980-1037) whose ideas were termed as the 'pinnacle of medieval period philosophy'. He presented a model of 'how far and in what way faith and philosophy can be reconciled'.

The Philosophy of Ibn Sina

Ibn Sina was born in Bukhara which at that time was supposed to be a part of Iran. This was the time when Iranians were trying to revive their old civilization. They had come to the conclusion that Islam was not another name for Arabic tradition. Accordingly, Iranians expanded the area of Islamic science by absorbing whatever valuable material they could obtain from Iranian, Greek or Indian cultural treasures. Firdausi compiled tales of pre-Islamic kings in his *Shah Nama*. Al-Beruni studied Indian sciences. Ibn Sina composed over a hundred books on medicine, philosophy, mathematics and Sufism. In medicine he was a follower of Galen. In logic and philosophy he believed in Aristotelian principles. In mathematics he had learnt the methods of Hisab Hindi (Indian arithmetic) and in almost all his works he used mathematical principles. His *Danish Nama-i-Alai* was called the 'Encyclopedia of Islamic Sciences in Persian'. In fact, various Islamic sciences reached Europe only through Ibn Sina's writings.

On the question of matter and Creation, Ibn Sina believed with Aristotle that matter had always existed. But at the same time his faith in Quranic doctrines was also unshakeable. He did accept God as the Creator but in his view the doctrine of continuous creation and atomic theory were wrong. His argument was that even the minutest part of matter could be divided into two. This division might not be possible physically or in practice, but in imagination it could always be done as in mathematics. For example, if we take a very small number, its half could also be imagined, yet the nature of the existence of divided and undivided number remained the same. In developing his line of thought, his knowledge of mathematics was helpful. Basing his argument on principles of Euclidean geometry, motion, and number theory, while applying the method of proof by contradiction, he 'demonstrated' that an entity like Jawhar al-fard or al-juz al-ladhi la yatajazza did not exist at all. Thus the very foundation of Mutakalimin's atomic theory was demolished. For example, when a grinding stone moved, on completion of one revolution the parts nearer to the centre traversed much less distance than did the parts near the edge. The reason was that the inner circumferences were much smaller than the outer circumferences.

In other words, when the outer circle moved one Jawhar-length, the Jawhars on the inner circle moved much less, although the grinding stone was moving at a uniform speed. The only inference that could be drawn was that different parts of the grinding stone separated so as to move at different speeds. But we saw ourselves that the parts of the grinding stone did not separate. Hence, inescapably, one of the Jawhars must have split. And this led to the conclusion that if Jawhar did exist it could be further subdivided.

It is to be noted that, here, the hypothesis of atoms was 'disproved' not on the basis of logic but by so-called 'observation and experience'.

In the revolution of the grinding stone, Ibn Sina took recourse to the laws of rectilinear motion, although if the laws of circular motion were applied no logical contradiction would have appeared because for all particles, whether near the centre or far away from it, move uniformly subtending an equal angle at the centre, the rotatory velocity would have remained the same. In fact, this was no proof at all; here, technical terms were used without a care for their applicability.

Non-existence of Khala

Having disproved the existence of Jawhar, Ibn Sina inferred that *Khala* (vacuum) also did not exist. When Jawhars themselves were non-existent, where did the question of emptiness between them arise. There is no reason why a *Jism* (body) should not be compact. The reason for apparent emptiness was that, owing to the particular shape of the body, all its parts might not exactly fit into each other. Even if we assumed that Khala existed, there would be another Khala inside it, whose emptiness could be less or more. Then, inside the inner Khala there must be another Khala and this sequence of Khala inside Khala might never end.

This meant that Khala possessed extension and it could be subdivided indefinitely. Thus the only conclusion that could be drawn was that Khala was neither a *Shai* (thing) nor a *La-Shai* (non-thing); besides, it could not be a property either. So, the Aristotelian dictum was right that 'vacuum is only a hollow concept'. Besides, experience also confirmed this view. For example, if a jug full of water was speedily rotated in the air, the water remained where it was; if Khala existed, nothing could have stopped the water from falling. Besides, the speed of anything that moved in the air would be limited, howsoever fast it might move. If Khala existed at least something would move with unlimited speed. But experience shows that no such motion ever takes place. This only proves that Nature abhors Khala.

Ibn Sina's Theory of Space

The atomic theory or concept of Ibn Sina also had a different view of Space. It was impossible to imagine Space as separate from material factors. Every material thing or body consisted of two basic factors: (i) matter or *Hayula* (*Hyle* in Greek); and (ii) form of the body. Hayula might or might not be felt, but the form of the body would definitely be felt due to its expanse when the body was formed within its boundaries. If there was no boundary, space or expanse would be meaningless. Thus the 'position' or space of a body was the sum total of the boundaries that it enclosed. For example, if water was kept inside a tumbler, then the surface of the tumbler which touched the water was the place or space of the water. Thus, Space had no existence by itself. It should be understood as a sum total of bodies bound by boundaries only. Thus, instead of considering the nature and character of Space, Ibn Sina gave a detailed answer to the problem of what is expanse and what is its relation with boundaries. However, he did not present any new theory. According to Majid Fakhry[12] his ideas could be taken only as an explanation of Aristotelian philosophy.

There was another explanation of the problem of Space. Abu Ali Sina believed that every material thing or body had its own 'natural' place, but it did not get its own place due to unfavourable circumstances. So the body had a feeling of imperfection, and it sought that very position which was completely fixed with its nature. This seeking was called motion. Accordingly, bodies moved in order to attain perfection. In a sublunary world motion would take place in a straight line because bodies would always take the shortest distance to gain perfection. Accordingly, if there were no obstructions, air and fire would always rise straight above and water and earth (soil) would always move downward. However, the principle of motion in the heavens was different because there everything was perfect; and therefore, motion in the heavens was circular as this was the only perfect motion in which the distance from the centre always remained the same.

Theory of Motion

In Ibn Sina's philosophy, motion did not simply mean change of place by a body. According to him, it was supposed to be forging from potentiality to actuality in time, either in a continual or a non-immediate manner.[13] This concept of motion became the basis for his views on time. While agreeing with Aristotle that time was the measure of motion, he further asserted that the feeling of motion came with the feeling of time; but time could not be perceived without motion. Space could be measured in terms of some selected unit, but man does not possess any ability of measuring time directly. If things did not move from one situation to another, how could the concepts of 'earlier' and 'later' arise? Hence, if there was no change there would be no time. But the Heavens were in perpetual revolution and motion was always taking place. This undoubtedly led to the conclusion that time always existed.

If there were no Heavens, then directions, motion or time would not exist either. Since motion had no atoms, time also could not have any Jawhar. However, for dividing time in imagination or measuring motion according to common practice, it might be possible to partition time into year, month, day, hour and Aān. Contrary to the Asharites and other Mutakalimins, who claimed that Aān was a Zamani-Jawhar (time-atom), Ibn Sina asserted that any small measure of time could be taken as a *Hadd* (limit) and Aān could be only such a Hadd which existed only in imagination.

Conclusion of Ibn Sina

In propounding his views on time, space and motion, while criticizing the theology-oriented theories of the Mutakalimins, Ibn Sina used a lot of technical terms from physics and advanced mathematical proofs. But in fact, he did not consider these problems from the material point of view. For him physics was 'ilm-i-zirin' (low-grade science) and mathematics 'ilm-i-mianagin' (medium-grade science), because in the latter the arguments were based on logic and generally there was no scope of ambiguity or contradiction. However, observation and logical analysis could throw light only on the apparent and outward aspects of an entity. At the most, its relation with the manifestation of Nature could be seen, but the mystery of its existence could not be understood through those sciences. The real science was the *Ilahiyat* (metaphysics), which he called the 'ilm-i-barin' (superior-grade science).

Ilahiyat deals with the problems of existence, quiddity of beings and correlation of their external manifestations with internal aspects. Ibn Sina did not believe that the world was devoid of order, dependent on chance only. He asserted that the world was orderly, harmonious and organized, because the existence of everything was dependent on the Dhāt-i-Mutlaq (Absolute Being), who was Himself perfect. Therefore, the objective of theoretical sciences should be to understand the science of the existence of things on the basis of Ilahiyat (metaphysics). Accordingly, Ibn Sina did not think that physics and mathematics were unnecessary or wrong. These were important sciences because they prepared the mind for understanding the superior sciences.

But, it must be said that the task that Ibn Sina had set before himself was not easy. As Afnan puts it, his views could be called 'the product of crisis in faith'. For him Islamic doctrines were basically correct, but he did not want to accept traditional faith blindly without applying the test of reason, although he nearly always realized that it was not always possible to prove a truth. However, when he came across any contradiction between common faith and philosophy he did not try to reconcile the two forcibly. In fact, no other Islamic thinker had brought out the similarities and dissimilarities between Islam and philosophy as clearly as did Ibn Sina while evolving his Ilahiyat. For that matter, it was not always possible to avoid logical inconsistency in questions of metaphysical nature. The importance of Ibn Sina's contribution to human thought lay in his emphasis on the need for tolerance and the use of rationality in problems involving faith. And this approach is valid even today.

Al-Ghazzali and his Falasafah

The most important Muslim scholar of the medieval period was Abu Ḥāmid Moḥammed Ibn Mohammed al-Tūsi al-Shāfāi Al-Ghazzali. He was born 21 years after Abu Ali Sina's death in eastern Iran near the town of Tus (modern Meshhad) in village Ghazzal. After elementary education in Tus he learnt *Ilm-i-Kalam* from Abu'l maali Al Juvaini in the madarsah of Naishapur. Al Juvaini was supposed to be the greatest scholar of Kalam which included atomic theory. He considered it necessary to know the views of others to defend Islamic faith. Al-Ghazzali learnt the doctrines of Sufism and practiced all its rituals. But Sufism did not satisfy him. By the age of 20, he arrived at the conclusion that traditionalism and the practice of rituals was wrong. So, he began to take interest in resolving the difficulties of Islamic laws and theology. He stayed for eight years in the madarsah of Naishapur and left when his teacher expired. He spent a few years with the court scholars. At the young age of 33, he got a chair at the prestigious Madarsah-e-Nizamiya in Baghdad, which was the most important university of the time. There Al-Ghazzali was counted amongst the top scholars.

In AD 1094 Al-Ghazzali wrote *Maqasid-ul-Falasafah* (The Objects of Falasafah), in which he dwelt on *Tahafat-ul-falasafah* (inconsistency of falasafah), which gave an idea of Al-Ghazzali's nature. During his four years' stay in Baghdad, he arrived at the conclusion that one could not rely on any particular system like Islamic laws, basic faith or philosophy. The human brain could achieve peace only through *Jazb* (absorption), but this could not be achieved through human effort; it was a gift from God only.

Ghazzali's attitude towards philosophy was not totally negative. If Islamic philosophers had said much about Islamic faith, it did not mean that philosophy was totally wrong. He was against philosophy on account of metaphysics. The philosophers attempted to understand the reality of the Universe on the basis of metaphysics, but in such matters use of brain and intellect was not sufficient. Whatever arguments were advanced by philosophers could not be proved on the basis of intellect alone. The main conflict between falasafah and Al-Ghazzali was about the time of existence of the Universe. The falasafah stated that the Universe had always existed and was eternal; but Al-Ghazzali believed nothing except Allah and His Attributes. According to him God had always existed and He created the rest. To show that the Universe had not always existed Al-Ghazzali advanced a mathematical proof. He claimed that if he believed the Universe to be ever-existent, he would also have to believe that the revolution of every heavenly body was infinite. However, in one revolution of the *Falak-ul-Aflak* (the sky of heavens), Saturn's made 12,000 revolutions, the Sun's sky 36,000 revolutions, and the Moon's sky completed 4,32,000 revolutions. Thus, this infinite number would be its own multiple of 12,000, 36,000 and 4,32,000. Obviously, no number could be smaller or greater than its multiple by one. Therefore, nothing of the infinite time could exist. This meant that the revolutions of the skies was not infinite nor had the Universe always existed.

This erroneous mathematical argument was presented in the sixth century AD, when a Christian priest named Philoponas established a Christian society 'in order to face the infidel scholars and converting ordinary Christians into true Christians'. He asserted that any attempt to understand the timeless on the basis of Time would only lead to errors. According to W.G. de Burgh,[14] Ghazzali only added an example. This argument was not mathematically correct. Yet, the theological circles among Muslims and Christians for a long time did use this argument to prove God's timelessness and creation of the Universe and Time. Strangely, even at that time[15] it was known that zero multiplied by any number resulted in zero. Accordingly, it could be inferred that the revolution of every sky was zero, but this would go against daily experience and observation, because with the change of weather and bright-dark phases it would not be possible to deny the revolutions of at least the sun and the moon.

Al-Ghazzali's Concept of Time

The real basis of Imam Ghazzali's theory was that Allah was omnipotent and that He created the Universe at some definite time, and thus Time was also created 'indirectly'. Time and Universe had definitely coexisted but the Universe was *Khariji* (external) and Time alone was *Izafi* (relative). This meant that Allah existed earlier without the Universe and later He and with Him the Universe coexisted. In other words, Allah's nature was existent while that of the Universe was non-existent; later on, both the natures were coexistent. In this context the earlier existence only indicated that the nature of Allah was *Wahid-ul-Ahad*.

In this exploration two terms were specially important: (i) the existence of the nature of a Being; and (ii) the non-existence of the nature of a Being. There was no need for assuming the existence of any other nature besides these two. However, the human mind believed that, to combine the two natures, a third nature was necessary. This product of the human mind, that is, *lazimi izafat* (essential relativism), is Time. Imam Ghazzali did not infer from his theory that Time did not exist although most Greek philosophers did not make a difference between 'mental' existence and non-existence. Ghazzali only asserted that Time had not existed always. Its existence as 'mere relativism' had been since the Creation. It was only through time that the relationship between 'before' and 'after' of the events was established and the movement was felt.

Ghazzali's Views on Space

Imam Ghazzali claimed in his *Tahafat-ul-Falasafa*[16] that there was no basic difference in the nature of Time and Space. Expanse in Time was understood by means of relativism of 'before' and 'after' while Space expanse could be understood in terms of relativism of 'upper' and 'lower' or 'right' and 'left'. Just as the human mind was not ready to accept that 'before' creation of Time nothing like Time existed, similarly it could not accept that beyond the boundary of the Universe there was nothing 'like Space'. We could see that for every body there would be some other body also outside it. This body might be air. Expanse was amongst the properties of the body. If there was any body outside the Universe, it would have been counted as a part of the Universe. If it was said that beyond the Universe there was only vacuum, how could this statement be accepted because vacuum was 'non-existent' and 'non-existent' could not be called 'existent'.

Al-Ghazzali believed that beyond the limits of the Universe nothing like 'space' existed. He argued that if philosophers could believe Space to be bounded, why could they not on the same basis believe that Time was also limited. Thus, according to him, the religious dictum that Universe and Time were created stood established. The Universe was created in its Time and Space with its properties due to the fiat of Allah and so it exists.

The existence and non-existence of everything depended on two factors: (i) God's intention; (ii) God's potence. The Universe came into existence on a desire of Allah after the absence of desire. Whatever shape it took could not be bigger or smaller and it could take the same form which it took. Thus, the will of God took a particular shape and all things, including Jawhar and Arāḍ, came into existence due to His will. His will was not bound by Time and Space. The consequence of these views was that Imam Ghazzali finally reached the point from where he had started. His childhood was spent in an atmosphere of Sufism and he studied Shariat theology. Later on, doubting everything, he turned towards philosophy and in this period he covered the entire field of investigation—philosophy, logic and other sciences. He finally began to believe that the key to opening the secrets of Truth could not be obtained by torture of the brain and that only he who was endowed by God could understand the secrets of Nature. As Fazlur Rahman[16] asserted, 'In spite of his open revolt against philosophy, it is very difficult to say how much philosophy he really gives up, because whatever he wrote is based on Sufism.' He more or less accepted all those principles of philosophy which he had rejected in his earlier writings. In theology he asserted that Asharite principles were perfectly correct. Thus he finally began to believe that the Omnipotent Allah continuously created Jawhar and Arāḍ. By his *Tahafat-ul-Falasafah* he warned against mixing religion with philosophy and asserted that attempts at proving religious dictums through mental exercise was fruitless.

By the twelfth century many amongst Muslim scholars began to take more interest in problems of Tasawwuf, Sufism and Shariyat (Islamic principles). However, Imam Ghazzali could not be held responsible for this state of affairs, but his writings did help Muslim scholars to devote more attention to these subjects at the cost of others. Imam Ghazzali himself was counted amongst the great philosophers of the world, but according to W.G. de Burgh,[17] Ghazzali's philosophy was essentially the philosophy of the heart. His heart accepted the reality which his intellect could not prove, because his heart knew what his intellect could not understand.

Lessons from History

A study of the ideas of Time and Space, even from the religious point of view philosophized, invariably led to the question: Did this Universe have a beginning or not, and if yes, when did it come into existence? But no convincing answer has yet been found, in spite of the best efforts of human minds. The solution to this riddle summed up by an Indian Sufi saint, Baba Nanak, in the *Jap Ji Sahib* is as follows:

> Kawan subela wakhat kawan si war
> Kawan si tru mah kawan jit hawa akar
> Wel na paya panditi to likhni lekhu Purāṇa
> Bhed na payo kadia ki likhni lekhu Quran.
>
> What was the auspicious time and what was the auspicious day
> What was the season, what month when creation took place.
> The Pandit did not get any idea to write an article entitled Purāṇa.
> The Qazi could not learn the secret so that he could add an article in Quran.

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CHAPTER V

History of Chemistry and Alchemy in India from Pre-historic to Pre-modern Times

Vijaya Jayant Deshpande

I. INTRODUCTION

The origins of Indian chemistry lie in the earliest use of various materials to make articles of everyday use, like pottery, bricks and metalware. From there it progressed through the ages and developed into a highly advanced metallurgy, producing a number of alloys like bronze, brass and bell-metal, rust-free iron as used in the iron-pillars of Delhi and Dhar, and extra-hard wootz steel for making swords and other sharp-edged weapons, both in India and foreign countries. Other useful chemical arts and crafts, which originated in the prehistoric and Vedic times, also flowered by the medieval period. Rise of alchemy in the late medieval period saw the theoretical and experimental side of Indian chemistry. In short, the story of Indian chemistry is the narrative of a glorious early start of chemical activity with a vibrant period during the medieval times. The story, however, came to a standstill by the seventeenth century AD. It was revived in the late nineteenth century, after Indian chemistry was exposed to modern chemistry and other sciences, by the newly English-educated class of scholars. It is not a complete story, because a lot of historical material remains to be explored; indeed, even the available material has not been completely studied.

There are three ways of investigating the history of sciences and technologies: through archaeology, through literary records, and through study of techniques in the areas where a continuous tradition existed until recent times. All the three modes are taken recourse to for obtaining definite inferences. Archaeological findings tell us about the time, place and pattern of chemical practices, whereas archaeo-chemical studies help us to know about the materials used, their compositions and the techniques employed. Literary sources provide not only definite dates of various developmental events but also present the socio-economic and religio-philosophical matrix in which these originated.

In the Indian context, written records are available from the Vedic age which is dated back to 1700 BC. *Ṛgveda* being the earliest of Vedas is the earliest literary source. Then come the *Brāhmaṇas*, *Purāṇas* and *Upaniṣads*, which tell a great deal about the Vedic and post-Vedic pattern of life. For pre-Vedic history we have to rely only on archaeological findings. Mohenjo-daro and Harappa, which now form part of Pakistan, were the earliest excavated sites. Excavations at these places began rigorously in the early twentieth century. Artifacts found here as also the remains of settlements throw much light on the civilization that flourished on the banks of river Indus or Sindhu, Ravi, and Kalibangan or Saraswati. This civilization lasted over a millennium from 2500 BC to 1500 BC.

From prehistoric times through Vedic (1700 BC to 500 BC) and post-medic or Buddhist period (500 BC to AD 600), the path of chemical development was quite simple, essentially involving accumulation of factual knowledge through metallurgy and other chemical arts and crafts. There was hardly any attempt to give explanations for the observed processes or to invent new processes. During the Tāntrik or alchemical period (AD 700 to AD 1300), on the other hand one could discern a merger of hands and brains, in the sense that specific goals (namely, gold- and silver-making) were marked and experiments were carried out to achieve them. Thus, Indian chemistry broke fresh ground during the alchemical period. Alchemical experiments were conducted on a small scale since they involved the use of very pure substances, including precious metals. The alchemists tried to explain the observed phenomena with the help of the then established alchemical theory. These experiments were primarily carried out by people who were experts in *Āyurveda*, the ancient Indian medical system. The alchemists discovered a number of substances and processes and established the primacy of India with respect to these discoveries. The most distinguishing feature of this period was that the details of the experiments were zealously noted down, which included ingredients, their measures, and successive operations. Though the alchemical products were rarely preserved, the theory and practice were well documented in medieval alchemical texts, through which important aspects of medieval chemistry could be studied.

Even though Indian alchemical theory was discredited in the course of time, as it was in other parts of the world, chemical arts and crafts continued to develop during this period. These two independent streams reinforced each other through accumulation of more and more factual knowledge, which eventually formed the basis of modern chemistry, that emerged as a part of the scientific revolution in seventeenth-eighteenth century Europe. It is hardly logical to say that India could have formed the seat of the scientific revolution if the political and consequent economic factors were not adverse. Yet, a favourable condition would certainly have led to large, economically sound chemical industries, which were nipped in the bud by adverse policies of the foreign rulers.

A number of scholars consider it meaningless to brand the ancient and medieval chemical practices as successes or failures in the light of modern science. They prefer to consider them as successes if they answered the necessities of the time. On our part, we would prefer to judge them with respect to both their usefulness in the contemporary context as well as their drawbacks which hindered their transformation into modern science of chemistry.

In the above context the story of Indian chemistry and alchemy could be divided into four parts:

1. History of chemistry in India from prehistoric to pre-tāntric period (up to AD 600)
2. Chemical arts and crafts
3. History of alchemy
4. The later developments.

In the following pages we would discuss these topics to provide an account of chemistry and alchemy in India since prehistoric times. Recent researches in the fields of archaeology, history of chemistry and metallurgy are also included in this account, to the extent possible.

II. HISTORY OF CHEMISTRY IN INDIA FROM PREHISTORIC TO PRE-TĀNTRIC PERIOD (UP TO AD 600)

Pre-Vedic Period Including Indus Valley Civilization:

The Indus valley settlements were the earliest habitat which could be distinguished from earlier settlements in having a uniform civilized pattern depicted in the remains of streets, public baths, temples and granaries. They also had the remains of mass production of a particular kind of pottery, houses of baked bricks, and especially a script of their own. So, we begin the story of early chemistry in India from here.

Pottery could be safely regarded as the earliest chemical activity in which materials were mixed, moulded and fired to achieve desirable qualities. Metal-working and other chemical practices like brick-making, production of glass beads and use of minerals for ornamental purpose came afterwards. These early settlements extended up to the Rajasthan dessert. Pieces of pottery found here varied in shape, size and colour. They were chemically analysed to get an idea of the materials used and methods employed in making them. These analyses show that the prehistoric people knew the art of making pottery using burnt clay. Metal-ores were added to it to get the required colours: for example, iron-ore was added for red and brown, copper-ore for blue and green, and manganese-ore for black and maroon shades. The earliest hand-made pottery was found in Uttar Pradesh, north Gujarat, Kashmir, West Bengal and Andhra Pradesh.

Coloured and wheel-made pottery was found at Harappa which was one of the centres of the Indus valley civilization. The pottery was decorated with numerous designs including geometric and floral patterns as well as human and animal figures. Mica was a prominent ingredient which enhanced the strength of the pots and also provided protection against cracking. Wood or charcoal was used as fuel. Underground furnaces of various shapes, sometimes lined with bricks, were used. The kiln atmosphere varied from oxidizing in the case of iron-ore, for producing shades of red, to reducing for manganese-ore for producing shades of grey and black. Glazed pottery was found at Mohenjo-daro, the earliest occurrence of such pottery in the world. In the later part of the period, black and red pottery was found in western India, in the region from Rajasthan to north Deccan.

Metals and Metal-working: Metal workers of pre-Harappan period knew only about copper. But during the Harappan period copper, lead, sliver, gold and alloys like bronze and electrum had became known. Iron was not known in this period.

Copper was more often obtained from Khetri mines in Rajasthan than from Afghanistan. It was used for making vessels, implements, weapons and other articles. Bronze statues were also made. A copper-arsenic alloy was used in place of low-grade bronze, since tin was scarce. Addition of tin or arsenic to copper while casting prevented oxygen bubble formation, since they acted as deoxidizers. These alloys were probably the results of using arsenical copper ores or those rich in tin. The bronze articles varied in their percentage of tin, which ranged from 4.5% to 13.20%. A large number of bronze articles had as much as 10% of tin, which suggested that it was deliberately added to get bronze of required hardness. Because of the scarcity of tin-ores in these parts, these might have been imported from other places like Persia. That nickel was invariably present in these bronzes suggested that the sources of copper were the ores from Khetri, Alwar, Singhbhum and Afghanistan, since these were known to contain both arsenic and nickel. A small percentage of lead was also present in copper and bronze. It rendered the metal or alloy more fusible and hence more suitable for castings. Addition of lead was perhaps unintentional; more likely it was an impurity. Hazaribagh and Rajputana copper-ores are rich in lead, as well as those from Afghanistan and Baluchistan.

It is evident from the above account that metallurgy was quite advanced in this period. Harappans smelted almost pure copper from sulphide ores and made tin and arsenic alloys of copper. Thus, hardening of copper using these elements was known since prehistoric times. Metal-forging techniques like field working, annealing, running-on, revetting and cire-perdue casting were also known to them. The Harappan metal workers even had the earliest tubular metal drills and the true saw.

As to the question whether copper-bronze technology of the Harappans was a direct import or a gradual indigenous development, the absence of any resemblance between Harappan and west Asian metal technology, on the one hand, and the individualistic features of Harappan copper base material, on the other, suggests some common basic technology on which the two grew independently, to suit the qualities of their individual ores. There is a need to carry out extensive excavations in these areas to prove this hypothesis.

Bricks: Bricks were manufactured on a large scale for making houses, boundary walls, public baths, etc. The bricks were remarkably uniform in size and were baked to improve their strength.

Glazed pottery: Pottery of the kind known as Faience was produced here. Powdered mixture of soda, silica, lime, colouring agents like metallic oxides were mixed with oil to make a paste. After the article was made, it was painted and fired at high temperature to create a glaze on the surface. Apart from pottery, glazed beads were found at the Indus valley sites. Seals and bangles were also made from the same materials.

Cement: Gypsum cement was found to have been used in the construction of a well in Mohenjo-daro. The cement was light grey and contained sand, clay, traces of calcium carbonate, and a high percentage of lime.

Minerals: A number of minerals were used by the Indus valley people in a variety of useful products. These minerals included cerrusite (carbonate ore of lead) and cinnabar (mercuric sulphide), used in cosmetics and medicinal preparations; galena (lead sulphide) used for making eye-paints; and white lead (lead carbonate) and steatite (soap-stone) used in plasters, hair-washes, etc. The Harappans also knew the technique of dyeing cotton with madder roots.

Gold and silver: The noble metals gold and silver and their alloy electrum (gold 20% silver 80% approximately) made their first appearance in the Harappan culture. Gold was exclusively used for making ornaments. Silver, apart from ornaments, was used for making vessels and seals. Gold was probably imported from Mysore. Gold ornaments were found at Lothal, Rajodi, Tekkalakota, Kausambi, Nevasa, Nasik, Nagarjunakonda, etc. Apart from Kolar, mines at Hutti in Raichur district (Mysore), Ramagiri area in Anantpur district and Wynaad area in Nilgiri district (Tamil Nadu) were also the possible sources of gold, according to some scholars. Primary mineral ore of silver was not available in India. Silver objects were excavated from the Indus valley sites. Copper hoards from Gangeria also yielded some 102 pieces of silver plates. Some scholars consider the mines of Afghanistan and Armenia as probable sources of silver in ancient India; some others think it might have been obtained from either electrum or argentiferous galena from a Burmese source. There is an evidence of alluvial gold-washing, in the fact that gold-dust was paid as a tribute to Darius. Rivers of Maharashtra, Bihar and Madhya Pradesh flow over such rocks and yield dust rich in gold. Gold from Kolar and Hutti is light in colour and is essentially electrum. Gold from Harappan sites resembled it. This means that gold-mining at Kolar must have started as early as that period.

Separation of silver from lead ore or gelana: Gelena was roasted to get lead containing silver. It also contained impurities of antimony, arsenic, copper and tin. Lead along with silver melted before the impurities did; the former were therefore made to flow out. On cooling, lead crystallized out and was separated using perforated ladles. This process separated some 85% of lead. The remaining lead was separated using the cupellation process. Literary evidence of the use of these methods are available in Kauṭilya's *Arthaśāstra*, a fourth century BC text. Medieval Sanskrit alchemical texts like *Rasaratnasamuccaya* and *Dhāturatnamālā* also mention this method of silver-lead separation.

Production of gold: Gold usually occurs in native state. Its higher density was made use of in its separation from other earthy matter and sand. After pulverizing the large pieces, water was added and the whole mass was agitated whereby lighter matter flowed off and heavier gold particles settled at the bottom. The gold particles were finally heated in a clay crucible over charcoal fire.

Separation of silver and gold from electrum: Silver was probably separated from gold by either of the two processes which were commonly used in ancient times. One was the salt process in which common salt when heated with electrum converted silver into its chloride and left gold unchanged. The second process involved conversion of silver into its sulphide by heating with antimony sulphide. Silver sulphide or chloride was further cupelled to obtain pure silver. Harappan silver was found to be associated with lead; hence the surmise that it was extracted from argentiferous galena ores. Silver plates obtained from copper hoard sites contained 4% gold or more—which went to show that the silver must have been separated from electrum.

Amalgamation process for separation of gold: Scholars like Munn and Mahadevan found, near the Wandalli and Honkunni gold-working sites, crucibles which were used in ancient gold-extraction. These crucibles when analysed, were found to have traces of mercury, which suggested the use of amalgamation process for separation of gold.

The Vedic Period (1700 BC to 500 BC)

The Indus valley civilization slowly disintegrated around 1700-1500 BC, due to the attacks of nomadic tribes from the north-west. After this, no civilized settlements appeared till the advent of the Aryans. The Aryans first settled in the regions inhabited by the former Indus valley people, and later migrated to the fertile land on the banks of the river Ganges. This period is characterized by the fact that it has both archaeological and literary evidence to support the dates of its beginning and thriving of the settlers. The literary evidence is chiefly provided by the sacred, religious texts of the Aryans, namely the four Vedas, *Ṛgveda, Yajurveda, Sāmaveda,* and *Atharvaveda,* in chronological order. The *Ṛgveda,* the earliest of the Vedas, is supposed to have originated between the fifteenth and twelfth centuries BC. Its hymns give some idea of the culture of the Aryans.

Gold, silver, copper and bronze are mentioned in the *Ṛgveda.* Gold was used primarily in ornaments whereas utilitarian objects were made from the other metals. The *Ṛgveda* also mentioned a metal Āyasa, recognized as iron by most of scholars.

There were a number of aspects of *Ṛgvedic* material culture which depicted one kind of chemical activity or the other. The fermented juice of the plant Soma [*Sarcostemma viminalis* or Acidum (Roxb) Voigt], called Somarasa, was supposed to bestow divine powers and even immortality. Apart form Somarasa, other alcoholic liquors like Surā (barley beer) and Madhu (honey beer) were also mentioned in the Vedas. Tanning of leather and dyeing of cotton was also practiced during that period.

After the *Ṛgveda,* the other three Vedas were composed between 1100 BC and 700 BC. *Yajurveda* mentions two more metals: tin (Trapu) and lead (Sīsā). *Atharvaveda* of which Āyurveda is a part is chiefly a medical text. Roots of alchemical ideas are noticed in its Rasāyana part, which is one of the eight sections of Āyurveda. This point is further elaborated in the section on alchemy.

The Aryans made a particular kind of polished grey pottery known as P.G. ware, which was dated to 1000-800 BC by the technique of radio-carbon dating. Other varieties of pottery, for example, red or northern black-polished N.B.P. ware, were also made by them. A major landmark of this period was the advent of iron. We will deal with this and other topics like cosmetics, glass, and liquors, which originated in the Vedic and Āyurvedic periods but developed significantly in the later post-Vedic or Buddhist period, in the second section on Chemical Arts and Crafts.

After the Vedas came the classical texts like *Brāhmaṇas, Upaniṣads* and *Purāṇas,* which were written in the post-Vedic or Buddhist period (500 BC to AD 500). They also contain stray references to these chemical activities.

Kauṭilīya Arthaśāstra (*KA*) was a literary landmark of this period. It was written by the Prime Minister of the Maurya emperor Candragupta who reigned in the fourth century BC. Viṣṇugupta by name, the Prime Minister was famous for his insight into politics, administration and war tactics, and was therefore called Cāṇakya or Kauṭilya. A treatise on political economy, *KA* touched upon all aspects of contemporary life, and as such, it was an important historical record of the time.

In the chapter on the working of mining and factory, *KA* largely deals with metals and metallurgy. It gives guidelines as to what a mining minister ought to know; it instructs a mining inspector what to know about copper-ores, quick-silver, location of ores, treatment of ores, how to distinguish ores by their colour, weight or odour, and it describes location and characteristic features of gold, silver, copper, lead, tin and iron ores. There are instructions as well for the coin-inspector on moulding copper coins, to which some 25% of iron, tin, or lead was added.

Production of salt from the sea and collection of shells, diamonds, pearls and corals were common practices, as was evident from the instructions given to the salt inspector. If salt was imported from other states, one-sixth of the imported salt was required to be given as tax. Salt production without permission of the ruler was subject to fine, as was its adulteration. Further, the amounts of tax to be paid by mine explorers were also noted.

KA gave detailed sets of rules for the gold inspector. About seven varieties of gold were described: Jambunāda, Sātakumbha, Hāṭaka, Sṛngisūktija, Jātarūpa, Rasaviddha and Ākarotgata. Four kinds of silver described were Tutthotgata, Gauḍika, Kāmbuja and Cakravāla.

Also described in *KA* were successive additions of copper to gold to produce different colours of gold; testing of a gold-piece using a touchstone; a test for gold using the solution of cinnabar, yellow or green vitriol, and cow's urine; making blue, yellow, white, green, parrot-green and dove-coloured alloys of gold with lead; and a number of silver alloys with copper and gold.

The text also contained an article on the goldsmith's business with rules laid down for him, including wages. Various modes of embezzlement were described to protect the owner of the precious metal (i.e. the employer of the goldsmith). All this was to show that the art of extraction and purification of noble metals and of making gold jewellery had reached great heights at the time *KA* was written.

Caraka Saṁhitā and *Suṣruta Saṁhitā* were two celebrated Āyurvedic treatises on medicine and surgery written by Caraka in the first century AD and Suṣruta in the second century AD, respectively. Chemical knowledge of the times, especially that related to medicine, was compiled in them.

Caraka Saṁhitā (*CS*) mentioned nine sources of spirituous liquor: cereals, fruits, roots, wood, flowers, stems, leaves, barks of plants and sugar from various sugar-yielding canes. Some 84 kinds of alcoholic drinks were made from them. Caustic alkalies had a special mention in *CS.* They were classified into two categories: the first could be used for internal administration and the second was used for external applications.

Suṣruta Saṁhitā (*SS*) described the preparation of alkalies in detail. Burnt ashes of plants were used along with limestone in these preparations. There was an interesting statement regarding the neutralization of an acid with alkali. The author explained how the sharp burning caustic property of the alkali disappeared by the addition of acidic extract of fermented rice. Caraka and Suṣruta knew about the tonic value of a number of minerals. They described a method of roasting iron to get its soluble salt which was used as a tonic. Suṣruta mentioned arsenic compounds like arsenic oxide and sulphide and recognized them as poisons. It appears that mercury was not used in medicines in this period.

Taxila: Let us now once again scan through archaeological evidence to construct the story of chemistry from Caraka-Suṣruta's time to the fifth century AD. This was the period when the great monastery at Taxila, the largest seat of learning of the time, was flourishing.

A series of explorations were carried out at Taxila which lies in the north-west of India. Archaeological finds of Taxila represent life and achievements of a period between 500 BC to AD 500. Pottery pieces unearthed at this place did not differ much from those found at Mohenjo-daro and Harappa. They included oil and wine flasks, water jars, ink-pots and drinking cups. A curious find was a water condenser; it was possibly employed to get the essences of plant extracts. A portable crucible made of sandy clay as well as painted and glazed articles were among other findings at Taxila.

As regards metals and metallurgical practices, it was observed that copper and bronze were used to a lesser extent pointing to the scarcity of copper and tin. A variety of iron articles including utensils, weapons, carpenters' and blacksmiths' tools, horse-bridle, elephant-goads and agricultural implements were found at Taxila. Scissors and spade were found for the first time here. Glass beads of about 500 BC, chiefly made of soda-lime-silicate were also discovered.

It appears from this account that metal-working, iron- and steel-making, glass, pottery, etc., had reached a highly developed stage by the end of the Āyurvedic period. A number of chemical arts and crafts also progressed and reached excellence. These are taken up for discussion in the next section.

III. CHEMICAL ARTS AND CRAFTS

The main chemical arts and crafts, which originated in the early civilizations like the Indus valley, the Vedic and the Buddhist, were glass-making, pottery, jewellery-making, metal-working, dyeing of clothes, tanning of leather, etc. They flourished in the early medieval period, partly due to improved skills, innovations, and contacts with foreign countries, and partly due to suitable economic conditions in the established empires. A number of new chemicals were used and new methods of manufacture were discovered. Through this expanded chemical activity the factual knowledge increased. The artisans came to know more and more about the materials they were handling, their properties and reactions with each other. They could now make a better choice of ingredients and processes which led to a variety of improved products. Out of innumerable chemical activities of this period, the following, were the major ones which contributed to the development of medieval chemistry.

Glass

Glass is a fused solid mixture of a number of substances like sand, lime, alkali and metallic oxides. It is brittle and it lacks a crystalline structure. It is of various kinds—transparent, opaque, coloured and colourless. Silica, lime and alkali (soda potash) give rise to transparent glass. Glass is used for decorative purposes (e.g. glass beads, bangles, etc.) and also for making containers and seals.

The earliest appearance of glass was noticed in Mesopotamia, as early as 2600 BC. It was also made in Egypt around 2000 BC. But glass became known in India much later. No glass objects were found at sites of the Indus valley civilization, except for some glazed articles. This is intriguing because glazing requires a technique similar to that of glass-making.

A powdered mixture similar to the one which produces glass on fusing, (e.g. alkali, sand, chalk and a colouring agent like metal oxide), to which an oil and gum is added, was coated over the surface of the pottery or bead to be glazed. It was then heated in an oven to dry. When fired at a high temperature, a glaze was produced. When the glaze entered the body of the ceramic article, it was known as porcelain. At Mohenjo-daro and Harappa a number of such articles were found, and at Maski in south India (1000-900 BC) and Hastinapur and Taxila (600-200 BC). An ancient glass factory was discovered at Kopia in Basti district of Uttar Pradesh. It was attributed to a period between the third century BC and fifth century AD.

Glass and glazes were coloured by the addition of colouring agents like metals oxides. Tin and antimony oxides gave rise to opaque glass. Different metallic oxides used for producing specific colours are listed below:

1. Red: Cu_2O, Cu (red haematinum)
2. Black: $MnO + FeO$, $FeO + CuO$
3. Orange (opaque): $Cu_2O + SnO$
4. Deep violet: high percentage of MnO
5. Chocolate: $Cu_2O_3 + Fe_2O_3$
6. Greenish: FeO
7. Turquoise blue: CuO
8. Bluish violet: $MnO + CuO$
9. Green: CuO
10. Bluish green: $CuO + Fe_2O_3$
11. Deep blue: CoO
12. Amethyst: $MnO + Fe_2O_3$
13. White: Sb_2O_3, SnO_2
14. Yellow: Fe_2O_3
15. Brown: $FeO + MnO$
16. Bottle green: Fe_2O_3

These pigments are found at the ancient sites, in the form of tablets or capsules. The glass-makers also knew about decolouring of objects by fusing the manganese content.

Literary sources like *Rāmāyaṇa, Bṛhatsaṁhitā, Kauṭilīya Arthaśāstra* and *Śukranītisāra* mention the use of glass. Similarly, foreign authors like Pliny, Strabo and Periplus also refer to glass in ancient India. They indicate a period from 800 BC to 500 BC as the beginning of glass manufacture in India. Chemical and microscopic examinations of ancient glass objects were carried out to find their composition and properties and to study the development of glass-making in India. These revealed the following facts:

1. Absence of lead and barium in most glass objects distinguish Indian glass from Chinese glass which contained large amounts of these materials.

2. The art of glass-blowing was dated as far back as last decades of the first century BC. This was supported by three sea-green flasks found at Sircap, which being also annealed before were well preserved. Annealing removed internal strain and checked devitrification. Glass tiles were also recovered at Taxila, near the Dharmarājikā Stūpa.

3. Some glass articles possessed relief designs. Besides, special glass beads were found, one having a layer of gold-foil in it and another with a milliflori pattern in which the core was blue with multicoloured decorations around it.

The above facts suggest in ancient India glass-making was quite widespread and a high degree of perfection was reached in this art. Since glazed objects were found at the sites of the Indus valley civilization, and since glazing and glass-making involved essentially the same chemical processes, it was likely that glass-making was known in India as early as that which might be proved by further excavations. Another astonishing fact about ancient glass was that the vermilion-coloured glass objects from Nasik greatly resembled in chemical composition similar materials from Mohenjo-daro. This fact supports the earlier suggestion regarding the knowledge of glass-making by the Harappans. Although there is evidence of glass-manufacture at Taxila, no glass-furnaces or factories have been excavated there so far. One possible site of a glass-factory was Kopia in Basti district of Uttar Pradesh, where glass fragments and lumps of unworked glass were found in large quantities. Further, glass slag was found at Kolhapur, Nevasa, Paunar and Maheshwar. Considering the high silica contents of Taxila glass, 6-7% of magnesia and lime, and 17.5% of alkalies, some scholars regarded Indian glass as distinct from that of Assyria, Egypt and Rome. They suggested an indigenous origin for ancient Indian glass. Glass furnaces of late medieval period were found at Mysore. It is possible that similar furnaces were in use in the ancient times as well. A large domed furnace had a round opening at the top and another opening for feeding the fuel at the bottom. There was a platform at the centre of the furnace where crucibles for melting glass were kept. Earthen crucible with molten glass stuck to it are found at Kopia. The Mughal period (AD 1526-1707) saw the flourishing of the art of glass-making in India. Glass spectacles were used in the early sixteenth century AD; possibly these were introduced by the Portuguese into India. Manufacture of spectacles from quartz was in vogue at Tanjore in the late eighteenth century. Modern glass industry, with high technical standards, came into being in the twentieth century.

Iron and Steel

In view of the fact that India had the richest deposits of iron ore, and that iron and steel metallurgy had reached great heights during the early medieval period as evidenced by the production of wootz steel from which the famous Damascus swords were made, one would have expected an early advent of iron in India. On the contrary, the iron age in India started much later. Both archaeological and literary evidences suggest that iron became known only during the Vedic age (1700 BC to 500 BC). The earliest literary source to mention iron was *Ṛgveda*, the earliest of the Vedas. It mentioned a metal Āyasa which probably referred to iron. In his very illuminating article M.N. Banerjee gave innumerable instances from *Ṛgveda* and concluded that in Vedic literature, *Hiraṇya* signified gold, Rajata silver, and Āyasa iron. Further, he quoted a number of textual examples where the claws of the king of Gods were compared to Āyasa, arrows were tipped with it, and *Agni* (fire) was said to be edged with it. Thus, Āyasa was supposed to be a very hard, tough, tenacious, malleable and ductile metal. Karmāra was the term used for ironsmiths. Quoting *Taittirīya Saṁhitā* and *Śatapatha Brāhmaṇa*, Banerjee stated that the metal Āyasa was purified using fire, bellows and hammer, that is by smelting in a furnace where air-blast was provided and the product was hammered to get the pure metal. From the description of the properties of the metal and its method of separation Banerjee recognized Āyasa as iron.

It appears that the *Ṛgvedic* smith manufactured steel from magnetic iron oxide in an open hearth made of mud, using bellows, after adding the dried medicinal plant *Cassia auriculata* Linn. At the time of fusing, bird's wings were added for carbonization. Finally, the fused mass was hammered to get steel.

The archaeological evidence agreed with the literary one. The pre-Harappan metal workers knew only about copper, whereas during the period of Harappan civilization bronze, lead, silver and gold became known. Although iron ore was used to get red and brown pottery, the metal was not yet separated. At the sites of settlements in the Gangetic and Yamuna plains, along with decorative painted grey ware, ceramic pottery and iron objects like arrowheads, nails and chisels were found in Punjab, Madhya Pradesh, Rajasthan, Maharashtra and Bihar. In south India also, iron objects as old as 1000 BC were discovered.

Excavation carried out at Taxila revealed settlements of a period between 500 BC to AD 500. Iron objects found at these sites varied from household utensils to arms and armour, horse-bridles, elephant-goads, carpenters' tools and agricultural implements. Miscellaneous articles like needles, plummets and unwrought ingots were also found. Spade and scissors found belonged to the first century AD.

Though the beginning of the iron age in India cannot be pin-pointed, some conclusions can be drawn from archaeological data. Early excavations had indicated an earlier date for the iron age in south India than in north India. However, recent excavations at sites like Taxila, Kausambi and Hastinapur supplied evidence suggesting a still earlier appearance of iron in the Ganga-Yamuna doab region than in the south. Considering iron slag and ore discovered in Hastinapur dated 1100-800 BC and in Kausambi dated 885-815 BC, a date in the ninth century BC is considered as a more possible beginning of the iron age in India. From the excavations in eastern Uttar Pradesh, Bihar and Central India it appears that iron-working must have begun around seventh century BC at these sites.

Knowledge of iron-working spread to Orissa and south India around 400-200 BC in three phases. We see that the application of iron and steel rapidly grew from spearheads and arrowheads to knives, sickles and finally to household utensils. Thus, starting form the eleventh century BC in the Ganga-Yamuna doab, the knowledge of iron-making spread into all parts of the country by the second century BC.

Chemical and metallographic analyses of ancient slag deposits as well as of the artifacts give an idea of the nature of the metallurgical operations employed and the kind of ore used. A low percentage of carbon in the products suggests that carburization must have occurred unintentionally, in most cases; on the other hand, higher carbon percentages of the order of 1.1% suggest intentional carburization of the oxide ores in the reduction process using charcoal. If some of the slag contained large amounts of iron oxide, it was possibly due to reoxidation of iron owing to high CO_2:CO ratio during the operation. The metal workers must have with practice realized that excess of carbon retarded the reoxidation, which must have led to better yields of pure iron. Perhaps the melting point of iron, which is 1540°C, was not reached by the furnaces employed. Yet, a temperature of 1100°C must have been reached which allowed the slag to flow out with ease. The slag was further removed by forging.

The late advent of iron in India is attributed to (a) the high temperatures needed for iron forging whereas relatively low temperatures are needed in copper-bronze metallurgy, and (b) until steel-making came to be known, iron had no particular advantage over copper. Similarly, bronze (90% Cu-10% Sn) was much harder than wrought iron. Non-availability of iron articles from times earlier than the first millennium BC could be partly attributed to the corrosive nature of iron, and to the fact that the smiths found it convenient to collect scraps to remake articles rather than extract new metal from the ore. Since very few iron artifacts have been scientifically studied no general conclusions could be drawn in this regard.

In the post-Vedic period, *Suśruta Saṁhitā* described a large number of surgical instruments possibly made of steel. The iron pillars of Delhi and Dhar of the fourth and seventh centuries AD, respectively, stand testimony to the remarkable skills of the iron-smiths, since these pillars have hardly rusted even after more than 1500 years.

High corrosion resistance of these pillars is attributed to high phosphorus (0.144%) and low sulphur (0.006%) content and absence of manganese. It is also likely that a film of magnetic iron oxide (Fe_3O_4) has formed on the surface of the pillars, protecting them against rusting. Specific treatment like successive heating and quenching, after applying a mixture of salts, produces a thin film. Such processes are described in some alchemical texts. The iron pillar at Delhi is over 24 feet high and has a diameter of 16.4 inches at the bottom and 12 inches at the top; it weighs over 6 tons. The tribals of Madhya Pradesh, Maharashtra and Bihar use some primitive methods to smelt iron ore even today.

Wootz Steel

Although the advent of iron in India was a late event compared to that of copper and bronze, its technology developed very fast.

Indian iron and steel was famous for its quality, especially for the hardness and sharpness of the edges of weapons. The earliest reference to this effect was in the fifth century BC. Klesias at the court of Persia mentioned two swords made of Indian steel, which were presented to him by the Persian king. Again, in the fourth century BC, Alexander the Great was presented with hundred 'talents' weight of steel by Pauras, the Indian king. Periplus stated that Indian iron and steel were exported to Abyssinia in the first century AD. One comes across numerous instances of this kind in later centuries as well.

The culmination of steel technology was seen in the famous wootz steel of south India, produced there since the sixteenth century AD. It was consumed both domestically and internationally on a large scale. A high carbon steel, it was made in ceramic crucibles made of clay and rice husk. The process involved reduction of magnetic iron ore using wood and leaves of specific plants.

The crucibles were formed of a refractory 'red loam' mixed with a large proportion of charred rice husk. Wood of *Cassia Auriculata* and leaves of *Asclepias gigantea* or *Convolvulus laurifolia*, were used for reducing the iron ore. The smelted iron was refined by repeated heating and hammering. The ingots were then cut into pieces of half a pound to two pounds in weight. They were packed in a crucible with one-tenth part by weight of the chopped dried wood and the whole mass was then covered with green leaves. The mouth of the crucible was filled and luted with clay. Twenty to twenty-four crucibles were kept in a furnace and heated in the blast for two and a half hours. After cooling, cakes of steel were obtained. They were again heated for several hours below their melting point in hot air blast to eliminate excess carbon. Later, these cakes were hammered into short bars and sold locally in this form. Wootz steel was also made in places like Jabalpur and Darjeeling. It was used for making edged tools which were tempered by plunging them hot into water.

Fire was made of charcoal and bellows were used for blowing in air, which enabled the crucibles to reach a high temperature. After heating for 24 hours in closed crucibles in a highly reducing atmosphere at about 1200°C, ingots of white cast iron were obtained.

Wootz steel cakes were exported to Damascus for making sword-blades, which were valued for their sharp edges and beautiful, flowing water patterns on them. Wootz steel was mainly exported from places like Mysore and Salem.

The exact method of tempering which gave hardness and other qualities to the product is not known even today, although sophisticated scientific techniques have been tried to unearth it, using crucible remains from historical sites. Archaeo-metallurgical field-work in north Telangana has helped identify 93 sites of iron-smelting based on rich magnetite and lateritic ores.

Brass

Brass is an alloy of copper and zinc. The zinc percentage in brass varies from 20% to 40%. Brasses containing about 20% to 30% zinc are golden in colour and take good polish. Brass was mentioned in *Kauṭilīya Arthaśāstra* under the name Ārakūṭa. Caraka mentioned it as Rīti signifying its method of preparation by melting copper with zinc or smelting with its ores. Excavations at the sites of ancient Buddhist stūpas have unearthed brass articles. Brass was extensively used in ancient and medieval India for making utensils, images, idols and artillery. Brass articles dating back to the fourth century BC were found at Taxila. Brass articles containing less than 6-7% zinc were found at Atranjikhera (1200-600 BC). During the late medieval period, guns were made of brass since it was harder than copper. A brass statue of Buddha was discovered at Fatehpur which has an inscription on it, suggesting it to be a work of the sixth century AD. Huan Tsang, a Chinese monk who visited India in the seventh century AD. wrote about a vihārā or large hall constructed of brass. All this points out that large-scale smelting of copper and zinc ores to get brass, as also its working, were well known to Indians by that time.

Tāntrik texts like *Rasārṇava* and *Rasahṛdayatantra* mentioned brass and its synthesis by roasting calamine with copper. Earlier, brass was undoubtedly made using copper and zinc ores like oxide, sulphide, carbonate and sulphate. No separate name for zinc was known at that time. Rasaka (calamine) was known to give rise to a tin-like metal on roasting with carbonaceous matter in a closed crucible. A verse to that effect was found in the twelfth century text *Rasārṇava*. Some brass articles containing large percentage of zinc suggest that they were probably made by melting the two metals in the required proportion. It was experimentally proved that the cementation process for making brass did not yield brass with more than 28% zinc. A high zinc alloy (84%) called Bidari was used for ornamentation over gold and silver-ware, at Bidar near Hyderabad.

Zinc

Although brass was known since the post-Vedic times, zinc as a separate metal became known much later. There are several reasons for the late appearance of zinc. For one, zinc oxide, the main ore of zinc, could not be reduced below 1000°C and zinc formed at this temperature was in a vapour state, the boiling point of zinc being 923°C. Hence, special arrangements were necessary to collect and condense the zinc vapours thus formed. Secondly, at high temperatures, the zinc vapour got reoxidised. Therefore, a reducing atmosphere had to be maintained for which a closed crucible was necessary.

Calamine or zinc carbonate was the main ore of zinc. It was called Rasaka or Kharpara in Sanskrit.. A process for purification of zinc was given in Tibetan texts, which were translated from Sanskrit in eight-ninth century AD. Also *Rasārṇava*, the twelfth century text, mentioned a process for zinc extraction from calamine.

Although zinc was known to be a separate metal from Nāgārjuna's time, it did not bear a separate name; indeed it was referred to as a metal of the appearance of tin, that is, kūtilasankāsam. In later alchemical texts like *Dhātu-mañjari* and *Dhātukṛtyā*, which are works of the thirteenth to fifteenth centuries AD, zinc bore a separate name. It was recognized as the metal responsible for making brass from copper and was given names like Yasada or Yasadāyaka (one which conferred success in alchemical operations) which later changed to Jasada or Jasta.

Zinc was exported to Europe from China since about AD 1605. Its nature or process of extraction was not known to the Europeans at that time. It was spelt in a number of curious ways like 'tooth and egg' metal or 'Tutenag'. The Portuguese called it 'Tutenaque'. A white alloy of copper, zinc, nickel and iron was called by the same name, when it was exported from China to Europe in the early nineteenth century.

Tutenag was probably the twisted form of the original word tutthanāg used for zinc in south Indian languages (e.g. Tamil). It was formed by combining two words, 'tuttha' and 'nāg', and therefore meant a kind of lead (nāg) derived from tuttha or calamine (zinc carbonate).

It is probable that zinc was introduced to China from India in the late medieval period, alongwith its name Tutthanāg or Tutenag. Later, zinc and its alloys were exported to Europe from China under the same name, after the Chinese learnt the method of extraction of zinc from calamine from the Indians, who had this knowledge for more than four or five centuries.

The literary evidence regarding separation of zinc was supported by the archaeological excavations at Zawar in Rajasthan. A large number of broken retorts, ash and heaps of slag were found there scattered over an area of a few square kilometers.

The ore mined at Zawar was principally zinc sulphide with small amounts of galena. The ore was argentiferous and probably extraction of lead and silver was also carried out here.

Zawar mines near Udaipur were dated by radio-carbon method as belonging to the fourth century BC. But large-scale production of zinc was carried out from the thirteenth century AD, by the distillation method.

In the 1980, extensive archaeological investigations were carried out at Zawar which led to the discovery of the apparatus used for downward distillation of zinc, as was described in the Sanskrit alchemical text *Rasaratnasamuccaya.* The furnace was divided into two chambers. The upper one was the chamber for heating the retorts and the lower one was used for condensing zinc vapour. The upper chamber had an arrangement of 36 retorts in an upside down position, with their funnels opening into the other chamber. There was a perforated terracotta plate in between, through which the retorts opened in the lower chamber. A stick was inserted in each retort before charging and luting, to keep the charge in place and also to provide a way for the zinc vapours to escape. The charge consisted of zinc ore (chiefly oxide), common salt and carbonaceous matter made into balls. Sulphide or sulphate ore was roasted before smelting. When the furnace was heated zinc oxide was reduced to zinc in the vapour form. The reduction was continued till the blue flame of carbon monoxide changed to white, that of zinc. (It is interesting to note that a verse describing the colour change of the flame, signifying the completion of reduction of zinc ore was found in *Rasaratnasamuccaya*). Zinc vapours got condensed in the lower chamber.

Recent electron microscopic studies of the materials have revealed vitrification textures. Besides, phase studies using electron diffraction and X-ray diffraction methods have been used to examine the nature of various complex compounds of zinc formed in the process, with the aim of recovering zinc from the medieval deposits of retort residues.

Saltpetre and Gunpowder

The discovery of saltpetre (i.e. potassium nitrate) and its chief application in gunpowder mixture was a crucial factor in the history of chemistry. The knowledge of this potent chemical decided the destiny of a number of rulers and their kingdoms. A variety of literary sources in Sanskrit, Persian, Tamil, Chinese, etc. were found to refer to the Indians' knowledge of these materials at different periods of time.

Firearms were mentioned in ancient Sanskrit texts like *Ṛgveda, Atharvaveda, Kauṭilīya Arthaśāstra* and *Manusmṛti.* It appears that fireworks were made by the sixth century AD and were used in celebrations. Dandi in the sixth century AD wrote in *Daśakumāracarita* about a magic powder (*Yogacūrṇa*) made for this purpose.

A certain paragraph in the Chinese text *Shi-yao-er-ya* by Mei Biao referred to the visit of an Indian Buddhist monk to China in AD 664 and his knowledge of saltpetre, its extractions and application as a flux in smelting and also in transmutation of metals. This Indian monk also knew about the flame test for examining the samples of saltpetre.

Since there was no mention of firearms or fire-powder in *Kāmaṇdaki's Polity* (fifth-seventh century AD) or *Agnipurāṇa* (ninth century AD) these were probably not known at that time. From these two sources and the Chinese text it appears that, although saltpetre was known and extracted, its use as an ingredient in the gunpowder mixture was not known until the ninth century AD.

A verse in the Sanskrit alchemical text *Rasopaniṣad* (written around eleventh-twelfth century AD) narrated the preparation of a gunpowder mixture. The author clearly stated that what was prepared was a Sphoṭaka (explosive mixture): 'Seven salts are heated with alkalies; wax and sulphur are added to it; and an explosive mixture is said to have formed.' The salts refer to sea-salt, black-salt, saline-salt, ammonium chloride, Romaka, and potassium nitrate.

Here potassium nitrate, sulphur and carbonaceous matter from wax were enough to make an explosive mixture.

A Tamil text, *Bogar Karpam*, supposed to have been written around the twelfth century AD, mentioned potassium nitrate under the name Inangam ('one with great strength'). The Tamil texts also describe the preparation of fireworks using sulphur, charcoal, saltpetre, iron powder, copper salts, mercury, cinnabar, arsenic, camphor, etc.

Vasiṣṭha Dhanurveda (twelfth century AD) described Nārāca, Nālikā and Śataghna, which were two metallic arrows and a kind of cannon, respectively. The author also advised on how to store large quantities of Ranjaka (gunpowder) and Śataghna for protecting a fort.

Śukra-Nītisāra of Śukrācārya written in the sixteenth century AD mentioned gun and gunpowder. It also gave a recipe for a gunpowder mixture consisting of saltpetre, sulphur and charcoal in specific proportions. Following is part of the text in translation:

> The Nālikā is of two kinds, large and small, small ones are 45 inches long, have a stock of tough wood and a barrel of bamboo with a bore of three-fourth of an inch... The small Nālikās are carried by infantry and cavalry. The larger Nālikā has no wooden stock, it is made of steel and other metals and is carried on wheels. The small shot for smaller arms is made of lead or other metals, and the balls (golā) for the larger (Nālikās) are made of iron with or without a shot inside them. The gunpowder or Agni-cūrṇa is composed of 4 or 5 or 6 parts of Suvarci lavaṇa (saltpetre), one part of sulphur and one part of charcoal of plant Arka (*Calotropis gigantea* Linn), Snuhi (*Euphorbia Nivulla* Buch-Ham) and other trees burnt in a pit so as to exclude air. The ingredients are to be purified separately, ground to fine powder and then mixed. The mixture is next soaked in the sap of Arka and Rasuna (garlic), dried in the sun and reduced to a coarse powder like granulated sugar. There are many kinds of Agni-cūrṇa known to the experts, and they are composed of varied proportions of charcoal, sulphur, saltpetre, realgar, orpiment, calx of lead, cinnabar, iron filings, zinc dust, shellac, blue vitriol, resin of pines, etc. Some give out white light like that of the moon.

A sixteenth-century travelogue by John Mandelsco described extraction of saltpetre in Gujarat from black soil. Trenches made in the earth were filled with black earth, water was added to it, and the soil was mixed by treading over it. The mixed material was allowed to stand. After some time, the clear water extract was taken out from the trenches and led into another trench where it was allowed to dry and grow thick. After boiling and removing the scum, the solution was poured in earthen pots, wherein it thickened to give cakes of saltpetre.

Saltpetre was produced on a large scale in India in the seventeenth century AD. It was exported to England. The Bohras of Gujarat were experts in its production and refining. The fact that there was a flourishing saltpetre industry in India in the seventeenth century AD itself suggests that the use of saltpetre in gunpowder mixture must have been known to the Indians quite early, and probably before Babar's time.

The Banjārās of interior Gujarat brought it to Ahmedabad for sale. In the seventeenth century, the English and the Dutch tried hard to buy saltpetre directly from the producers, to be free from interference from the State's Muslim or Maratha rulers, as regards the source, quantity to be bought and restrictions on its application.

The earliest mention of a gunpowder mixture in the world was in a Chinese text of the ninth century AD. The Chinese used rockets against the Tartars in the thirteenth century, and it was not until the late fourteenth century that they were used in Europe. Some scholars like H.M. Eliot and Dr Oppert are of the opinion that the Arabs learnt about firearms from certain translated Sanskrit treatises in the eleventh century AD, and then improved upon it. There are also suggestions that the words for gun (Banduq) and cannon (Tope) have their origin in Sanskrit words Piṇḍaka (for ball) and Dhūpa (for rocket).

Whether or not the Indians knew about the gunpowder mixture as used in fire-arms before the Muslims used it in the fifteenth century AD, is still a controversial point.

Words like Tu-fang (musket) and Tope (cannon) were used in *Mufarrih-ul-Qutub*, a book compiled in India in the thirteenth century, which contradicted the claim that it was Babar who first introduced the cannon in India. In fact Babar wrote that Bengali soldiers were skilful gunners. In the fourteenth century AD Mohammed Shah Bahamani-I got 300 gun carriages as spoils from the Raja of Bijanagar.

From the aforesaid account it appears that saltpetre was known, extracted and used in fireworks even in the Vedic times. The Arabs came to know about guns and cannons through translated Sanskrit texts. The activity rapidly increased and a very large number of guns and cannons were made after the sixteenth century, a period of wars and instability.

Paper

Paper was probably introduced to India from China through Tibet in the eleventh century AD. The western parts of India appear to have acquired the knowledge of paper-making from the Arabs who learnt it from the Chinese. Formerly, Tālapatra (palm leaves) and Bhūrjapatra (bark of the birch tree) respectively were used as writing materials by Indians.

From I-tsing's accounts it appears that paper was known in India in the seventh century AD, although it was a rare commodity at that time, probably imported from China.

In the initial stages, the process of paper-making was simple and more or less alike in all parts of the country. A pulp was made from cleansed rags, hemp, old sacks, fishing nets and jute. Lime and soda were added to whiten the pulp. Gum was added to the pulp to give the sheet of paper the required strength. A wire-sieve was then dipped into it. When lifted up, it brought a thin sheet of the material with it. This sheet was removed, pressed and dried by hanging in the sun. It was then polished using a pumice-stone, a piece of wood or a shell. The dried paper was glazed with rice-water mixed with alum.

Sialkot, Zafarabad, Murshidabad, Ahmedabad, Aurangabad, Mysore, etc. were the main centres of paper-making in medieval India. Paper from Ahmedabad was very white and glossy. The city produced a surplus quantity of paper, which was exported to far-off countries.

Cosmetics and Perfumes

We come across a large number of references to cosmetics and perfumes in Sanskrit literature. These are found either as complete treatises on the subject or as entries in encyclopaedias like *Bṛhatsaṁhitā* of Varāhamihira (AD 500), *Mānasollāsa* of Somadeva (AD 1120) and *Agnipurāṇa*. Some scanty references are also found in novels, poems, etc.

Two treatises, *Gandhaśāstra* and *Gandhayukti*, were discovered in 1944. Two more were discovered by P.K. Gode later—*Gandhasāra* of Gaṅgādhara and *Gandhavāda* by an unknown author—with commentaries in Marathi. Hence, these probably belonged to the late medieval period.

Cosmetics and perfume making were mainly practiced for the purpose of worship, sale and sensual enjoyment. *Pañcatantra* mentioned sale of perfumes, indicating it to be an age-old practice. It was customary to dilute these scents, which were called 'Attars', with pure sesame oil.

The Bower manuscript or *Navanītaka* was discovered by Dr A.F.R. Hoernle in 1890. It was supposed to be a work of the second century AD. It contained recipes of hair-dyes which consisted of a number of plants like indigo and minerals like Kāsisa (ferrous sulphate), iron powder, black iron or steel, and acidic extract of sour rice gruel called Śukta. Myrobalans were used as fastening agents. The dye had sesame oil as the medium.

Gandhayukti was a section in the encyclopaedic work *Bṛhatsaṁhitā* of Varāhamihira, written around AD 500. Though Gandhayukti literally meant 'combination of perfumes', it really signified 'art and science of cosmetics and perfumery'. It listed the following chemical processes involved in perfume-making:

1. Pakva or Pācana: decocting;
2. Tapta or Tāpana: heating;
3. Saṃyukta or Saṃyojana: mixing;
4. Pradhūpa or Pradhūpana: fumigating;
5. Sikta or Siñcana: sprinkling;
6. Bodha (Bodhana), Prabodha (Prabodhana) or Udbodha (Udbodhana): mixing of powders; and
7. Vedhana: blending one liquid into another.

Gandhayukti gave recipes for making scents for use in hair baths, hair oils and perfumes. It lists various combinations of eight aromatic ingredients, totalling 84. The eight substances are:

1. Rodhara (Lodhra): *Symplocos paniculata* Walt
2. Uśira: *Andropogon muriatus* Retz
3. *Bignonia Chelonoides*
4. Aguru: *Aquilaria agallocha* Roxb
5. Mustā: *Cyperus rotundus* Linn
6. Vana: *Vaṁśalocana*
7. Priyangu: *Aglaia roxburghiana* Miq
8. Pathyā: *Terminalia Chebula* Retz.

Any three of the above substances could be mixed with Sandal, Turuska (Bitumen), Śukti (Nakha, a fragrant substance) and one quarter of Śatapuṣpa (*Pimpinella anisum* Linn) and then fumigated with Kaṭuka (*Picrorrhiza kurroa* Royde and Benth), Asafoetida and Jaggery. Thus, 84 different scents were made.

Gandhayukti also presented recipes for mouth perfumes, bath-powders, incense and talcum powder. The incense was made of a combination of aromatic ingredients, an inflammable substance like lac, and a binder like jaggery or honey. An interesting entry relates to talcum powder made by powdering the mixture of certain barks of plants, musk and camphor. It is called Putavāsa. The author also gives a method for making a hair-dye using iron powder, acidic extract of rice gruel and a plant named 'Kodrava' (*Paspalum scrobiculatum* Linn). The paste of myrobalan is used as a dye-fastener.

Gode considered the degree of excellence and refinement in cosmetics and perfumes, current at any period of civilization, to be an index of the cultural development of that period. He quotes Gaṅgādhara's classification of aromatic ingredients from *Gandhasāra* as follows:

1. Leaves: holy basil leaves etc.
2. Flowers: saffron, campaka (*Michelia champaka* Linn), cloves etc.
3. Fruits: pepper, nutmeg, cardamom, etc.
4. Barks: bark of camphor and clove tree, etc.
5. Woods: sandal wood, fire wood.
6. Roots: nutgrass (*Cyperus rotundus* Linn) and vāta (*Pavonia Odorata* Wild)
7. Plant exudations: camphor
8. Organic products: honey, musk, lac, ghee etc.

Buchanan (nineteenth century AD) described the manufacture of rose water:

A large copper still which can hold 150-200 litres of water and has a flat head; fresh roses are put in it with water and a tube bent at right angles takes the water vapours carrying rose essence to the recipient copper vessel, which is placed in a wide-mouthed earthen vessel containing cold water which condenses the vapours thus forming rose water. Sandalwood oil is impregnated with essences collected in this manner from aromatic ingredients like Bela (*Jasminum Sambac* W.), Agar wood (*Acquilaria Agollacha* Roxb.), flower of Kevara (*Pandanus Odoratissimus* Linn) and the respective Attara or scent is made.

Soap

Ancient Indians used certain plants and their fruits like the soap-nuts of Ritha or Ariṣṭa (*Sapindus trifoliatus* Linn) and Śikākāi or Saptala (*Acacia Concinna* DC), also called Bahuphena (one which produces much lather), for washing clothes. Also, fruits like Bel or Śrīphala (*Aegle marmelosa* Corr.) and Sarṣapa (*Brassica campestris* Linn) were used to wash different kinds of clothes. Other substances used alongwith the above fruit-pulps or decoctions were ashes of plants and powdered salts like Yavakṣāra (impure potassium carbonates), Sarjikākṣāra (impure sodium carbonate), Usa or saline earth, and Gomūtrakṣāra (salt obtained from cow's urine).

There were references to these soap-like substances called Phenaka in second and third century AD texts like *Manusmṛti* and *Yājñavalkyasmṛti*. Throughout the first and half of the second millennia AD, a number of literary evidences to the use of soap-nuts in India for washing a variety of garments were found.

The earliest reference to soap (i.e. Sābaṇa) was found in Guru Nanak's prayers written in the late sixteenth century AD. The word Sābun appears to have originated from different words for soap, like, the Portuguese (Saboa), Persian (Sābūn), Arabic (Sabon) and Turkish (Sābun), all of which seemed to be closer to the Portuguese word. All Indian languages like Marathi (sābana) and Hindi (sābun) also had similar words for soap. Hence it appeared that soap was unknown in India before the arrival of the Portuguese in the late fifteenth century.

There is a possibility that the Bohris of Gujarat made soap of some kind in the thirteenth century AD. Similarly, some Marathi poets mentioned soap in their works in the thirteenth century AD. Thus, one might surmise that crude soap in the form of cake, possibly made from a mixture of soap-nuts, plant ashes, lime, natron, etc., was made in India around the thirteenth century AD. Later, the Portuguese introduced more sophisticated soaps in the sixteenth century AD. Indians definitely began to make soaps in the eighteenth century AD in Gujarat. They used oil of Eranda (*Ricinus communis* Linn), seeds of plant Mahua (*Madhuca Indica* J.F. Gmel), saline earth Usa, and impure calcium carbonate called Samudraphena. These soaps were used for washing clothes. Slowly scented, soft soaps for bathing were made. The earliest soap factories were set up in Calcutta, Kanpur, Meerut, Mathura, Jodhpur, Bombay and Bangalore.

Ink

Before paper was invented, Bhūrjapatra and Tālapatras were used as writing materials in India. The ink used on Bhūrjapatra for writing manuscripts was made of almond charcoal and cow's urine. This ink was waterproof.

During excavations at Taxila an ink-pot was unearthed which suggested that ink was known and used in India from the fourth century BC. The Kharosthi documents discovered at Khotan point to the fact that ink was definitely used in the first century AD. The Ajanta caves displayed some painted inscriptions which were written with coloured ink made from chalk, red lead and minium. India ink had been used by the Chinese, Japanese and Indians for quite a long time.

Mānasollāsa or *Abhilāṣitārtha-cintāmaṇi* written by Somadeva in the twelfth century AD mentioned lamp black for making black colour or Kajjala. Haritāla or vermilion was used to paint yellow any letters or portions to be deleted from manuscripts. The formulae for black, golden, silver and red ink were also known.

A thirteenth century AD Maharashtrian saint Jñāneswar mentioned Masi or ink. The recipe for ink was also given in *Rasaratnākara* of Nityanātha, an early sixteenth century text. Bhallātaka or marking nuts were used by washermen to mark clothes before washing. The ink made from marking nuts and myrobalans kept in water in an iron pot was black and durable. This kind of waterproof ink was used in Malabara and other parts of the country as well. Jain manuscripts, written in the medieval period, used a special ink prepared from roasted rice, lamp black, sugar and the juice of plant Kesurte (*Verbesina scandens*). This ink could be used for writing on paper; acacia gum was sometimes added to it, to give the necessary shine. The juice of *embelic myrobalan*, when placed in an iron pot, gave a dark solution containing dark-coloured iron compounds like the tannate. This solution was sometimes added to the above ink. It had its drawbacks, however, since iron compounds were injurious to the texture of the paper. For writing on palm leaves the Jains made an ink consisting of the juice of Kesurte mixed with a decoction of whole-wheat flour. It was very lasting.

Buchanan in the nineteenth century observed that ink in both liquid and solid form was made using lamp black collected by burning linseed oil, gum of the plant *Mimosa Indica* and water, all rubbed in an iron mortar using a wooden pestle. An infusion of gallnuts in water was added to it and further rubbed. Lastly, the pestle was dried to get dry ink. The Maharashtrian saint Rāmadāsa, of the seventeenth century AD also gave a recipe for making ink from lamp-black.

Tannins, a group of substances of plant origin, are amorphous powders, soluble in hot water and ether. Their solutions are coloured dark blue-black or greenish by the addition of ferric salts. It appears that this fact became known to Indians during the late medieval period, possibly after the thirteenth century AD, and they used these solutions for ink-making. When this ink was not found suitable for writing on paper, they returned to the age-old method of using lamp-black or charcoal.

These tannins react with proteins to form a voluminous precipitate. Therefore, they are used for removing the insoluble proteins from animal hides. What is left is leather. Tanning of leather was mentioned in *Ṛgveda* (1700 BC).

Tinning of Copper and Brass

Copper metal from copper and brass utensils form hazardous copper compounds when it comes in contact with acidic ingredients of food which are stored in these utensils. Therefore, these articles are coated with a thin layer of tin metal. This process is called Tinning or 'Kalai' in a number of Indian languages. Historical references to tinning were found in sixteenth-seventeenth century texts like *Ain-e-Akbari* (AD 1590) and *Rājadharmakoṣa* (AD 1676).

In this process the utensils were heated on the fire and the surface was cleansed using ammonium chloride with subsequent dipping in water. When tin metal, having a low melting point, was rubbed over the hot inner surface it formed a thin metallic coating on it. Tavernier (seventeenth century AD) in his book, *Countries Around Bay of Bengal* mentioned the discovery of new rich mines of tin in India and further remarked that tin was only used in this country to tin cooking pots, kettles and other copper utensils. From the above dates it appears that tinning was introduced to India by the Muslims.

Dyeing

The principal dye-producing materials were plants and their products, like madder, turmeric and safflower. Other materials included inorganic compounds like orpiment and some insects like lac, cochineal and kermes.

Excavations at Mohenjo-daro produced a purple coloured cotton which was supposed to have been dyed using madder (*Rubia cordifolia* Linn). It established the antiquity of dye-stuffs in India. There was also archaeological evidence of dyeing on an industrial scale since the third millennium BC.

A number of classical texts like *Atharvaveda* (1000 BC) mentioned dye-stuffs like Mahārañjana (safflower), Nili (indigo), Manjistha (madder), Lodhra (*Symplocos racemosa*) and Haridrā (turmeric).

In the medieval period alum was recognized as a colour-fixing agent or mordant, and it was widely used for this purpose. Later, in the eighteenth century, iron mordant was used for blue, green and violet dyes and aluminum mordant for fixation of red dye-stuffs. The juice of vegetables was taken out and boiled over fire. Every now and then it was tested to see whether the boiling was complete.

Some of the colouring agents of plant origin are listed below along with the part of the plant from which they originate and their specific uses.

	Dye	*Colour*	*Part of plant*	*Uses*
1.	*Morinda Tinctoria* Roxb. (Ach)	Red, yellow	Stem, root	Dyeing, printing
2.	Majetha: madder or *Rubia cordifolia* Linn	Red	Stem, root	Dyeing, printing
3.	Lac: *coccus lacca* (a resinous incrustation formed on the bark of trees by lac insects)	Red, scarlet, purple	Bark	Dyeing, printing
4.	Indigo: Nili *Indigofera Tinctoria* Linn	Blue	Leaves, flowers	Dyeing cotton
5.	Myrobalan: Hālila *Terminalia Chebula* Linn	Yellow	Bark, rind of fruit	Dyeing cotton
6.	Pomegranate: *Punica granatum* Linn	Greenish yellow	Bark, rind of fruit	Dyeing cotton
7.	Loth: *Symplocas racemosa*	Deep red, crimson	Bark	Dyeing silk
8.	Har Shingar: *Nyctanthes arbortristis* Linn	Yellow	Orange coloured stalks	Dyeing silk
9.	Kachnar: *Bauhinia variegata* Linn	Red, pink	Bark	Dyeing cotton
10.	Babul: kakar *Acasia Arabica* Willd.	Brown	Bark, leaves	Dyeing cotton
11.	Imli: tamarind *Tamarindus indica* Linn	Black dye by adding iron salts	Galls	Madder-dyeing, calico-printing
12.	Chakanda: *Cassia Tora* Linn	Blue	Seeds	Dyeing cotton yarn

Dyes were extracted from inorganic substances by repeatedly soaking and mixing them in water and allowing the material to settle. The clear solution was taken out and smeared on a pot and evaporated to get the dry dye.

Metals and minerals were mixed with natron (Svarjika) and lime (cunā) and the paste was boiled with cow's urine and water. The scum gathered at the top was removed till the remaining solution became clear. It was then filtered using a cloth. A container smeared with kāca salt was used to store this solution. It was then placed in another bigger earthen vessel and heated. The essence was then collected by distillation.

Some other substances having tinting capacity included plants like Kampillaka (*Mallotus Phillippinensis*), Pattanga (Cesalpinia Sappan) and Jatuka (a species of oldenlandia). Those of animal origin included Indragopa (*Cochineal*). Āyasa (iron), Kāsisa (sulphate of iron), Tūttha (sulphate of copper) and Anjana (sulphate of antimony) were some metals and minerals used for tinting purposes.

Synthetic dyes were made by the mid-nineteenth century. Later, synthetic indigo totally uprooted the native indigo-dye industry.

Calico-Printing

The ancient towns of Lucknow and Kannauj had a flourishing calico-printing industry. In the early seventeenth century the painted clothes were exported to Holland and Portugal. Later, Farrukhabad took over the industry and by the eighteenth century AD it became a prominent centre for calico-printing.

Earlier, two techniques were used for calico-printing: hand painting and block printing. By the eighteenth century AD, block printing almost entirely took over calico-printing. Bleaching the cloth, making it ready for printing, applying dyes by block printing, using resist-paste and applying the ground colour, and finally washing the cloth were the successive operations involved in this process. Alum solution was used as the fastening agent in hand painting.

For bleaching, a white emulsion made by mixing 5-7 lbs of castor oil (or equal parts of castor and sesame oil), two ounces of native alkali, a small quantity of powdered sheep dung, and water was used. Pieces of cloth were dipped in the solution, rubbed, wrung and then left on the ground for three to four days. The process was repeated till the cloth became white. Finally, they were washed with clean water.

The bleached pieces of cloth were then dipped in a mixed solution of powdered myrobalan, *Terminalia ballerica*, flowers of *Griselea tomentosa* (Dhawai), roots of *Nordo stachys* (Balchhar), coconut, roots of *Hedychium spicatum* Ham. (Kapur kachri) and roots of *Cyperus pertinius* (Nāgarmotha). This treatment prepared the cloth for painting or printing.

A black dye was made of 2 lb of ferrous sulphate, 3 gallons of water, 102 flowers of *Griselea tomentosa*, 6 lbs of the gum of *Anogeissus latifolia* Wal. (Dhaumar), 2 oz of ghee and 1 oz of wheat flour. The pieces of cloth were printed using this dye.

After printing with the dye, a resist-paste made of shell-lime, soap, gum *Anogeissus latifolia* and gum Acacia dissolved in water was applied over the print so that it remained unaffected by the ground colours. The ground colours used were:

1. *Basanti* (sulphur yellow) prepared from *Delphinium ajacis* Linn boiled in water or turmeric boiled in water and then mixed with curdled milk.
2. *Khaki* prepared from the solution of ground Babul pods in water.
3. *Pink* or *light pink* prepared from the solution of different strengths of madder in water.
4. *Sabz* prepared from pounded turmeric mixed with pomegranate rind to which European grey and green aniline dye were added.
5. *Sky-blue* prepared from the blue dye used in printing borders and patterns.

6. *Dove-grey* prepared from European violet dye mixed with the madder solution.
7. *Yellow-green* prepared from a decoction of ground turmeric, pomegranate rind and European green aniline dye.

After the application of the ground colour the clothes were washed in running water to remove the resist-paste.

Alcoholic Liquors

Somarasa, the fermented juice of plant Soma, mentioned in the Vedas, was probably the earliest literary evidence of the use of alcoholic liquors in India. *Kauṭilīya Arthaśāstra* (fourth century BC) mentioned the manufacture of liquor and ferments, while stating the duties of the superintendent of liquor. It also listed various liquors as Medaka, Prasanna, Āsava, Ariṣṭa, Maireya, and Madhu. They were prepared from various substances like rice, wheat flour, sugar, honey, jaggery and grapes.

A ferment called Kinva was prepared from the paste of grains of Māsa (*Phaseolus radiatus* Linn), rice, Morata or Ankota (*Alangium Salviifolium* Linn), etc.

A powder comprising of *Triphalā* (three myrobalans) and spices like long pepper, black pepper and cardamom was also added to the liquor to improve the flavour; probably it also served as the source of enzymes.

A decoction called Āsava was made from uncooked juice of plants (or fruits or grains) mixed with spices and Kinva and kept under the earth or in a heap of grains to ferment for a specific duration of time. A similar decoction prepared from cooked juices was called Ariṣṭa.

Caraka Saṁhitā also mentioned nine sources for making various Āsavas: cereals, fruits, roots, woods, flowers, stems, leaves, barks of plants, and sugar-cane.

It appeared that the Harappans also knew about the process of distilling liquor, since an assembly of clay articles similar to the distillation apparatus was reconstructed. Liquors were brewed in south India since the ancient times. Some 60 Tamil names were found in Saṅgam literature dating back to the first few centuries of the Christian era. In the coastal regions, liquor was made from Toddy or Palmyra palm (*Borassus flabellifer* Linn). The pot in which the juice was collected was smeared inside with Cūnā or slaked lime, to prevent excessive fermentation due to the hot climate.

Medieval alchemical texts also mentioned fermented liquors and their methods of preparation. In the fourth chapter of *Rasopaniṣad*, plants had been classified into various categories: for example, Mahāviṣas or strong poisons; Upaviṣas or weak poisons; Raktvarga which produced red flowers or juices; Āmlavarga which had acidic extracts; Bījavarga the seeds of which were useful in alchemical operations; and Surāvarga from which alcoholic liquors were made. A list of 13 Surāvarga plants was also supplied by the author:

1. Kuramula (*Ipomoea paniculata* R Br)
2. Visālu
3. Kancukī (*Carrissa Carandus* Linn)
4. Halā (*Cesalpinia bonduce* Linn)
5. Matsyākṣi (*Solanum nigrum* Linn)
6. Karati (Safflower)
7. Vajri (*Euphorbia antiquorum* Linn)
8. Ākhukarṇi (*Ipomoza reniformis* Chois)
9. Saputrinī
10. Rājakosātakī (*Luffa acutangula* Roxb)
11. Muktā (*Jasminum sambac* Ait.)
12. Muktamūlī (*Raphanus sativas* Linn)

13. Dravantikā (*Ricinus communis* Linn).

Alcoholic liquors were classified into following categories depending on their applications in alchemical operations:

1. Dāsanapāsanī Surā: used in dying operations
2. Sarvacāranī Surā: used in mixing operations of all kinds
3. Drāvanī Surā: used in dissolving substances
4. Rañjanī Surā: used in dyeing operations
5. Rasabandhanī Surā: used in binding mercury
6. Rasasampātanī Surā: used in distillation of mercury.

A process of making spirit from rice was described by J.C. Ray, as adopted by brewers of Orissa in the late nineteenth century. The process was similar to the one described above in *Kauṭilīya Arthaśāstra.* A ferment called Bākhar was used in place of Kinva. It was mixed thoroughly with cooked rice and kept for 24 hours. A mouldy vegetable composition, Bākhar induced the temperature of rice to rise and the fungus to grow. Again, an equal weight of fully softened rice was added to it. After adding a large quantity of water to it the mixture was kept in vats buried under the earth, for 8-10 days. When a gas started bubbling from it, distillation was carried out to obtain proof spirit.

A liquor called Mādhvī was commonly made from the flowers of the Mahuvā plant (*Bassia latifolia*), which were rich in fermentable sugars. Tribals living in hilly regions still manufacture this cheap, illicit liquor. Charles Hamilton wrote in the late eighteenth century:

> There is a very curious and useful tree, called by the natives of Bihar and the neighbouring countries, the Māhwah or Māwee. Its Sanskrit name is Madhūca or Madhudruma. It is of the classification of the *Polyandria monogynia,* of Linnaeus. The corolla of flowers, after being dried, are eaten by the natives raw, or dressed with their curries and when even simply boiled with rice, they afford strengthening and wholesome nourishment. They are indeed often applied to a less laudable purpose, for on being fermented they yield, by distillation, a strong spirit which the people here sell so very cheap.

Suṣruta-Saṁhitā used the word 'Kohala' for alcoholic beverages made from powdered barley. It was similar to the Arabic word 'al-kohala' and modern word alcohol. The use of curds was also well known to the Indians. Use of fermented drinks made from grapes, although known since the time of *Kauṭilīya Arthaśāstra,* became popular after Indians came in contact with the Greeks. Under British rule, the nobles and kings started drinking imported wines which greatly hampered the development of Indian breweries.

Pharmaceutics

Indian chemistry largely developed during the alchemical and iatrochemical period (AD 1100-1800) through pharmaceutics. Medicines were derived in the classical period chiefly from plants. Yet there were a few ingredients that originated from animals. Metals and minerals were also used in synthesizing medicines.

Preparation of medicines basically involved collection of the above ingredients, their purification, extraction of their essences, and compounding of these extracts by means of processes like grinding, pasting and maceration. Chemical processes like dissolution, distillation, sublimation, precipitation, combustion, dilution, and decocting were carried out in these preparations. The Rasacikitsā school relied more on mercurial preparations. Distillation of cinnabar to get mercury in its pure form was carried out as recorded in *Rasaratnasamuccaya.* Juices of a number of plants were used for purifying mercury. It was solidified using plant juices, metals and sulphur. Gold was also used in a number of drugs. Mercuric sulphide, known as Rasasindura or Makaradhwaja, was made by subliming a mixture of mercury, gold and sulphur in a covered crucible. Crystals of reddish brown mercury sulphide were thus obtained.

In this way, through pharmaceutics, the medieval Indian alchemists-cum-medical experts discovered a number of chemical and metallurgical processes, apparatuses and various inorganic compounds, thus greatly enhancing the progress of medieval chemistry.

Ornaments of Gold and Silver

The ancient art of making ornaments from gold and silver was practiced even by the Indus valley people. Gold being glittering yellow in colour and chemically less reactive was eminently suitable for making ornaments. Silver was also used for this purpose because of its colour and softness. Gold ornaments were reported from Lothal, Rajodi, Tekkalakota, Diamabad and Kausambi, as also from Adichanallur in south India and Nevasa and Nasik in Maharashtra. They were from the early historic periods. Gold ornaments were made in south India from very ancient times (2000 BC).

Ornaments made of gold and silver were also mentioned in Vedic literature. Addition of copper to gold, to make it harder and more workable, was mentioned in *Kauṭilīya Arthaśāstra.* It appears that embezzlements were not unknown in this period since Kauṭilya cautions the employer of smiths in this regard.

Making of ornaments, soldering, use of an alloy of zinc, brightening, and recovery of gold from solutions left after brightening, all involved a number of chemicals and processes. The goldsmiths were well aware of all of them. During the process of giving a particular shape to the ornament, or during soldering, the pieces had to be heated. Due to the small percentage of copper in gold, they got darkened, because copper was converted to cupric oxide, which was removed by dipping the article in a concentrated tamarind decoction. Thus, the article became bright yellow but the soldered part remained white. It was then dipped in a mixture containing nitre, common salt and alum. The dissolved gold particles then got deposited on the soldered surface forming a layer of shining gold on it. Sometimes ornaments were tinged red or violet by adding sulphur to the cleansing solution.

The cleansing solution, in the end, contained some proportion of dissolved gold. To recover it the solution was evaporated to get a solid residue. It was mixed with borax and cow dung. A mixture of partially oxidized lead, copper and zinc was then added and it was strongly heated in the hearth. Lead got removed as litharge and an alloy of gold-silver-copper was left behind. The individual metals were separated using various parting methods.

Small Scale Non-Ferrous Metal Industries

Bronzes (copper-tin alloys) which contained more than 20% tin were known as high-tin bronzes, bell-metal or speculum metal. They were traditionally employed in making mirrors, musical instruments like gong, cymbal and cell, and kitchenware. These bronzes were found to acquire properties like hardness and stiffness on slow cooling; similarly, sonority was produced by quenching them at a particular temperature. Also due to their high tin content, chances of food-poisoning were reduced. In Kerala, these articles have been made for over 300 years. Aranmula metal mirrors and Kadavaloor eating bowls and gongs were quite famous. This points to the knowledge and skill of high-tin bronze processing of artisans in Kerala.

Mirzapur has been famous for its brass and bronze industry. The artisans of Mirzapur, called Niyaras, collect scrap, dross and slag, that is all the rejects from non-ferrous metal industry and produce standard brass, bronze and copper-nickel ingots by refining in fire. They use a variety of furnaces to produce specific products like German silver, brass and bronze.

Several places in India, Bastar district of Madhya Pradesh, and Midnapore, Bankura and Burdwan districts of West Bengal, produce artifacts using metal-casting methods like open cast, part or closed moulds, or lost-wax or investment casting.

Sulphates of Copper and Iron

Copper sulphate had been known in India since ancient times. Due to its turquoise-blue colour it was named in Sanskrit as 'Mayur-greeva-tuttha (i.e. of the colour of a peacock's neck). It had synonyms like Tuttha, Tutthaka or Sasyaka. It was produced at the copper mines of Rajputana, Khetri and Singhana, by roasting copper pyrites, dissolving the mass in water, and evaporating the solution to obtain the crystals of copper sulphate. It was known to be a salt of copper, Bhāvaprakāśa writing in about AD 1500 said that it contained some copper and therefore possessed some properties of that metal. It was described in this work as astringent, emetic etc. It was purified by rubbing with honey and clarified butter, heating in a crucible, mixing with whey for three days, and drying. Pure copper sulphate thus obtained was even used for internal administration.

The sulphate of iron, copper or ferrous sulphate was called Harātuttah or Kāsisa or green sulphate in Sanskrit. It occurred as green crystals soluble in water. Naturally iron pyrites got oxidized to iron sulphate. Natural green copperas was found in many parts of India along with alum shales. It was synthesized from iron pyrites. Moistened iron pyrite was exposed to the atmosphere to form its sulphate, a solution of which on evaporation and crystallisation yielded iron sulphate. It was largely employed in the dyeing industry as a colour producer and mordant.

Alum

Alum called Saurāṣṭraja in Sanskrit was mentioned in *Suṣruta Saṁhitā.* It had synonyms like Kānkṣi, Tuvrari and Saurāṣṭri, which appeared in the *Amarakośa,* a seventh century synonymous dictionary. As the name signified it was abundant in the soil of the Saurashtra or modern Surat. At this place and also at Sahabad in Bihar it has been manufactured since the early historic times to modern times.

Alum shales were dug out and exposed to the atmosphere for four months. They were then spread out in the large pan-like squares and moistened with water until after 10-12 days, crusts were formed which called 'Phiṭkari kā bīja' or the seeds of the alum. The crusts were then boiled in large iron vessels lined with lime along with saltpetre obtained by the lixiviation of village refuse. (Nitrates from the refuse combined with the potassium carbonate to give saltpetre in solution and carbonates precipitated out.) Alum seeds (i.e. sulphates of copper and iron), when mixed with saltpetre in the proportion of 15:6, gave double sulphate or alum on crystallization. Alum was mainly used as a mordant in the dye industry. It was also used in Āyurvedic medicines.

IV. HISTORY OF THE ALCHEMY (AD 800-1300) AND IATROCHEMISTRY (AD 1300-1600)

Alchemy in India flourished in the medieval period. As in other world civilizations, Indian alchemy had two characteristic streams: gold-making and elixir-syntheses. The two faces of the alchemical practice, the metallurgical and the physio-religious, were superimposed to get a single picture wherein mercury and its elixirs were used in the so-called transmutation of the base metals into noble ones as well as for internal administration, for purifying the body, rejuvenating it and taking it to an imperishable and immortal state.

The ideas of rejuvenation, longevity and immortality, which became the basis of physiological alchemy could be traced to earlier historical sources. The belief that the liquid extract of the Soma plant was potent and was drunk by the Gods for achieving immortality was mentioned in Vedic literature. Other alchemical notions like that of gold being the purest and the noblest of all metals and that it could confer its imperishability upon others by mere contact were also very ancient. This notion explains the use of gold and its compounds in medicinal recipes. Buddhist literature of the fifth-sixth century AD also gave recipes for synthesizing medicines from the substances of plant and mineral origin, which could give great strength, long life and even immortality.

As for metallurgical alchemy, one finds references to brass-making and production of other kinds of gold-like alloys in Kauṭilya's *Arthaśāstra* (a text of the second-third century BC). The name for brass was Ārakuta. The same text described how to make alloys from metals like gold, silver, lead, iron, copper, etc., desirable colour. The use of mercury in making gold and coloured amalgams was also known in Kauṭilya's time as was evident from one of the verses in the same text.

The different kinds of gold were Jāmbūnadam, Śātakuṃbhaṃ, Hatakaṃ, Vainavaṃ, Śṛṅgisūktijaṃ, Jātarūpaṃ, Rasaviddhaṃ, Ākarotgataṃ, and Suvarṇam. Here Rasaviddhaṃ ('one obtained by treatment with mercury') was also included as a kind of gold. The inclusion of Hatakaṃ in this list is also an evidence of alchemical practice, since Hatakas were the elixirs made from mercury and other ingredients and which could transmute other metals into gold (or gold-like metals).

The Philosophy Behind Mercury

We come across evidences of alchemical practice in the true sense of the word, in the texts written in the medieval period. These texts primarily dealt with gold-making and elixir-syntheses. Elixir or Rasāyana was a substance which could transform other base metals into gold and silver, as well as confer longevity and immortality when taken internally. In fact, gold-making was looked upon as a test to be performed prior to administering the elixir. If an elixir proved successful in transmutation of metals it was supposed to be safe for internal administration as well.

The alchemist looked upon the transmutation of metals as their purification so as to bring them to an imperishable state, that of gold. This process was looked upon as identical to that of culturing the human body and making it indestructible. That these two processes were supposed to be parallel was evident from the following verse in *Rasaratnākara* of Nāgārjuna:

> I shall certainly tell you whatever is asked by you, i.e. remedies of warding off wrinkles and grey hair, and also stop ageing. These preparations can act with equal efficacy on the metals as well as on the human body.

Owing to its heavy weight, silvery white and shiny appearance, fluidity, and its property of readily combining with other substances, mercury was regarded as the most potent of the all substances and as possessing divine properties. This was evident from various names given to mercury like Mahārasa (chief of the all rasas) and Rasendra (king of all rasas)

Other names for mercury were Pārada ('one which leads us to cross the ocean of life'), Sūta ('originating from God'), Haribīja ('essence of God Śiva'), and Svarṇakāraka (gold-maker), the last one suggesting its alchemical applications. The potions containing mercury were suppose to give longevity and immortality, thus making it the main ingredient of the powders used in the transmutation and as elixirs.

Mercury had to undergo 18 processes before it could be used for transforming either metals or the human body. These processes were specified in the Rasāyana texts as follows:

1. Svedana: steaming or heating using water bath
2. Mardana: grinding
3. Mūrchana: swooning or making mercury lose its form
4. Utthāpana: revival of form
5. Pātana: sublimation or distillation
6. Rodhana: potentiation
7. Niyamana: restraining
8. Sandīpana: stimulation or kindling
9. Gaganabhakṣaṇa: consumption of 'essence' of mica
10. Caraṇa: amalgamation
11. Garbhadruti: liquefaction (internal)
12. Bāhyadruti: liquefaction (external)
13. Jāraṇa: calcination
14. Ranjana: dyeing
15. Sāraṇa: blending for transformation
16. Sankramaṇa: acquiring power of transformation or penetration
17. Vedhana: transmutation
18. Sevana: becoming fit for internal use.

A religio-philosophic base was given to mercury-based alchemy in India. Mercury was looked upon as the essence of God Śiva, and sulphur as that of Goddess Pārvati. Sometimes mica was also named after Pārvati as Gauri, since it was another name of the same Goddess and meant the fair one. A number of texts like *Rasārṇava* were written in the form of a dialogue between Śiva and Pārvati, wherein Śiva conferred the alchemical knowledge on Pārvati. A combination of male and female principles (i.e. mercury and sulphur) forming cinnabar or mercuric sulphide or even of mercury and mica, was supposed to be highly potent and was therefore consumed as a Rasāyana or medicine for increasing body fluids or vitality.

In Buddhist alchemical texts also one finds a parallel concept. For example, Prajñāpārimita ('one with boundless wisdom'), a name for the Buddha was supposed to confer alchemical knowledge to his disciples. Considering the popular humanitarian image of Buddha, it was no surprise that he fitted well as a conferer of knowledge of making elixirs, which have healing and rejuvenating properties. In fact, some of the minerals which were part of these elixirs did have some tonic effect on the human body.

Āyurveda and Rasāyana

The earliest mention of Rasāyana was found in *Āyurveda* which was probably composed by eighth or ninth century BC, since it was a part of *Atharvaveda*, the last of the four Vedas. Vedas were supposed to have been written between the fifteenth and the eighth centuries BC. Āyurvedic system is a very ancient tradition of Indian medicine. According to Caraka, the renowned medical practitioner of the first century AD, the original *Āyurveda* consisted of the following eight parts, Rasāyana being one of them:

1. Kāyācikitsā: therapeutics
2. Śālakya: the science of special diseases of the eyes, nose, ears, mouth, throat, etc.
3. Śalyapahartrka: surgery
4. Viṣagara vairodhikaprasamana: toxicology
5. Bhūtavidyā: psychiatric knowledge
6. Rasāyana: rejuvenation
7. Kumārbhṛtya: pediatrics
8. Vājikaraṇa: knowledge for increasing virility.

The earlier Āyurvedic treatises such as *Caraka Saṁhitā* make extensive use of plants and plant products in the synthesis of medicine. Metals like gold, silver, lead, copper, iron and tin were used in medicinal preparations. Minerals like iron pyrite, copper pyrite, and bitumen, and salts like common salt, alkaline salts, black salts and fossil salts were known to have medicinal properties. Certain compounds like orpiment, realgar, iron and copper sulphates and antimony sulphide were usually used in external applications. A combination of metals called Sarvaloha—which included tin, lead, iron, copper and silver as a finely divided powder in myrobalan juice—was known as a tonic. Sulphur was used in medicines, applied externally for skin diseases as well as for internal administration in the form of a suspension in plant juices, for asthma, cough and chronic skin diseases. Bronze was used for making apparatuses. Various salts, earths, alum, sulphur, quartz, etc., had internal as well as external applications.

It is interesting to note that mercury was not mentioned in *Caraka Saṁhitā*, nor was cinnabar (mercuric sulphide). Though 'Sindura' (i.e. mercuric sulphide or sometimes lead oxide) was known from ancient times, its use in elixir preparation was not known. Thus it appears that mercurial medicine was a later development in the history of Indian medicine.

Mercury was mentioned in texts like *Dhanvantari Niganthu* and *Rājniganthu*. In earlier texts, Rasāyana probably did not include mercury. Rasāyana in the sense of 'medicines derived from mercury' appeared in the medieval period during which a large number of alchemical texts were written.

Hindu philosophy tended to cultivate transcendental tendencies which influenced Indians for over two millennia. Yet, every now and then the elements of materialism came up in the form of Vṛātyas, as they were called. After the decline of Buddhism and before Śaṅkrācārya reinforced Hindu philosophy materialistic tendencies came to the fore in the form of Tāntrism. Hence, the period between AD 800 and AD 1300 was called the Tāntrik period in Indian history. The Tāntras offered to give the divine experience in this very life. Tāntrism advocated that preservation of body or Kāyā-Sādhanā was essential for attaining this goal. Here mercurial preparations assumed great importance and alchemy reached its peak during this period. A number of Tāntrik texts like *Kubjikātantra* and *Rasaratnākara* were written, which contained alchemy along with characteristic features of Tāntrism.

Tāntrism developed as a counter philosophy to the idealistic Vedānta philosophy, just like Taoism developed as a counter philosophy to Confucianism in China. Parallels between Tāntrism and Taoism, and the relation of Tāntrism to science were discussed by D.P. Chattopadhyaya in his work *Lokāyata* wherein he aptly stated:

> The concept of physical immortality and its connection with the alchemy of Tāntrikas is, again, strongly reminiscent of ancient Taoism. The Taoist, as Needham showed, were emphasizing the importance of certain techniques like the respiratory technique (Prāṇāyāma), the gymnastic technique (Āsana), the sexual technique (Rasāyana)—and all these for the purpose of attaining a state of material immortality. This conception of material immortality, he added, was of incalculable importance to science because it stimulated the development of the technique of alchemy. We have seen that precisely the same thing was said of Tāntrism by our Tāntrikas themselves, unlike the followers of the idealistic system of Indian philosophy who belittle the importance of the body and dream of the liberation of the soul. The Tāntrikas with their supreme emphasis on the material human body (Dehavāda) conceived liberation only in terms of the development and the culture of the body (Kāyā-sādhanā). It is no wonder, therefore, that they should have been so much concerned with concrete material measures that could ensure the development and the preservation of the body itself. This explains their contribution to alchemy and medicine. In short, the proto-materialism of the Tāntrikas was the clue to their proto-scientific tendencies.

Alchemical Texts of the Medieval Period

Numerous alchemical texts were written between the ninth and the fourteenth centuries AD. They contained a combination of metallurgical, protochemical as well as iatrochemical knowledge. Some texts (e.g. Tāntrik texts) are such that the alchemical ideas form only a part of them, while some other texts are wholly devoted to alchemy. Texts like *Mātṛkābhedatantra, Rasārṇavakalpa* and *Rasakalpa* fall in the first category. Those that come under the second category include the following:

1. *Rasahṛdayatantra* by Govinda Bhagwatpād
2. *Rasaratnākara* by Siddha Niṭyanātha
3. *Rasārṇava* by an unknown author
4. *Rasendracūḍāmaṇi* by Somadeva
5. *Rasaratnasamuccaya* by Vāgbhaṭṭa
6. *Rasaprakāśasudhākara* by Yaśodhara
7. *Rasarājalakṣmi* by Rāmesvara Bhaṭṭa
8. *Rasendracintāmaṇi* by Dhunḍukanātha
9. *Rasendracintāmaṇi* by Rāmacandra Guhā
10. *Rasasāra* by Govinda Ācārya
11. *Rasakaumudi* by Sarvajñacandra
12. *Rasabheṣajakalpa* by Sūrya Panḍita.
13. *Rasasaṁketakālikā* by Cāmunḍa
14. *Lohapaddhati* by Sureśvara
15. *Kankāligrantha* by Nasirshah (Hindi)
16. *Rasamuktāvali* by Devanātha.

There are many more texts which could be added to this list.

A number of alchemical texts, known as Muppu texts, were written in the Tamil language, by practitioners of the Siddha system of medicine. The more prominent Siddhas were Agastyār, Bogār, Rāmdevār and Karuvurār. Alchemy, with both its metallurgical and physiological characteristics, was clearly reflected in these texts.

There were alchemical texts written in other Indian languages as well, for example, Hindi, Telugu, Kannada, Marathi, Bengali and Oriya. The followers of the Jain sect also wrote such texts which were found in western India. These were essentially similar to the other texts in their alchemical content. Thus, it may be concluded that alchemy was much in vogue in India during the medieval period, and people of all languages and sects participated in it.

Endeavours of the Medieval Alchemist

The colossal nature of the activities of the alchemists was evident from the alchemical texts written in the medieval period. They used the earlier knowledge of metals, minerals and plant materials to design their methods as well as develop upon it from their own experience. Since in their methods the purity of the ingredients was of utmost importance, the alchemists greatly relied on various methods of purification. The substances frequently used in alchemical operations were metals like gold, silver, iron, lead, copper, zinc, tin and mercury. Also used were arsenic, sulphur, orpiment (arsenous sulphide, As_2S_2), realgar (arsenic sulphide, AS_2S_3) and cinnabar (mercuric sulphide, Hg_2S_2). Other compounds which were largely used in such operations included:

1. Iron or copper sulphate ($FeSO_4$ $7H_2O$ and $CuSO_4$ $5H_2O$)
2. Iron, silver or copper pyrites (metallic sulphides)
3. Sodium carbonate and chloride (Na_2CO_3, $NaCl$)

4. Ammonium chloride or sal ammoniac (NH_4Cl)
5. Potassium nitrate or saltpetre (KNO_3)
6. Borax ($Na_2B_4O_7\ 10H_2O$)
7. Calamine or zinc carbonate ($ZnCO_3$)
8. Lead oxide: minium, red lead (Pb_3O_4, PbO).

Different kinds of gems and mica occurred in a number of recipes. Animal derivatives like milk, ghee, wax, liquor, dung, honey, meat, urine and blood also had their application in alchemical methods. The transmutation processes, designed by the alchemists, were based on a few principal chemical operations, like making gold- or silver-coloured alloys from ordinary metals—which were sometimes amalgams—yellow sulphide film on the metal surface, or dyeing of the metal to a desirable colour with plant juices having dyeing properties. The techniques of tinging or colouring of metal using a number of combinations of inorganic salts and plant juices (containing various organic substances) were also known and practised by the alchemists.

The alchemists must have undoubtedly conducted several trials with different combinations of metals, salts and plant products, before arriving at the correct method. Also, for determining the right proportion of ingredients, adequate supply of heat and, for that reason, selection of the right kind of fuel and appropriate reaction-period, they must have carried out several repetitions of the same process. These activities made the alchemists acquainted with the physical and chemical properties of the various substances they used in their experiments.

Plants were extensively used in various syntheses. As a matter of fact, extensive use of plants and plant products was the one characteristic feature of Indian alchemy. They served a number of purposes, as in obtaining acids and bases of different strengths, as solvents, and as sources of carbon for reduction processes. The appropriate selection of plants in a particular process showed the thorough knowledge of the alchemists with respect to the plant kingdom. In the text entitled *Rasopaniṣad*, about 600 plants had been mentioned which were used in different alchemical methods. The contents of a few of the alchemical texts discussed below clearly depict the landmarks in the development of Indian alchemy.

Nāgārjuna and Rasaratnākara

The earliest available alchemical text in Sanskrit, *Rasaratnākara* by Nāgārjuna was probably part of a larger text *Rasendramaṅgala* written by the same author. Nāgārjuna was the most prominent personality in the field of Indian alchemy. He had also authored other texts like *Ārogyamañjari, Kākṣapuṭa Tantra, Yogasāra* and *Yogaśaṭaka.* There had been great controversy as to whether this alchemist was the same person as a Buddhist patriarch by the same name, who was a second century figure and of the founder of the Mādhyāmaka system of philosophy. Sir P.C. Ray has discussed this question in some detail, in the introductory part of his book, *The History of Hindu Chemistry,* along with a thorough discussion of Mahāyānism and its relation to Tāntrism and alchemy. Tārānātha wrote a biography of Nāgārjuna in Tibetan in the seventeenth century AD, in which he stated that Nāgārjuna was born and brought up in a Brahmin family of south India and was afterwards converted to Buddhism and also that he was a celebrated alchemist.

Kumārjīva, a central Asian monk, translated the *Life of Bodhisattva Nāgārjuna* into Chinese, as early as AD 401-9, which was included in the Chinese version of *Buddhist Tripiṭakā.* Considering the above facts, it seems quite plausible that the Mahāyānist patriarch Bodhisattva Nāgārjuna was also an authority on medicine and alchemy. *Rasaratnākara* of Nāgārjuna is a relatively smaller text than the later alchemical texts. A large part of it is devoted to metallurgical operations like extraction and purification of ores and metals. It is interesting to note that calamine (i.e. zinc carbonate), the main ore of zinc, was known in Nāgārjuna's time and it was used for extraction of zinc as well as in brass-making. This is evident from the following verses of *Rasaratnākara*:

> Rasaka or calamine is digested repeatedly with fermented paddy-water, natron, clarified butter and mixed with wool, lac, *Terminalia chebula* and borax, and roasted in a covered crucible when it yields an essence of the appearance of tin.
>
> What wonder is that calamine ... roasted thrice with copper converts the latter into gold?

Brass was not, however, recognized as an alloy but was termed as 'Kāñcana' or gold. It should be noted that zinc was not known in Europe until the thirteenth or fourteenth century AD. The Portuguese merchants who visited India in the tenth century AD reported having seen a metal resembling tin in appearance, which was called cālin or Cālaem and by selling which the Indians made a lot of money.

Zinc was exported to Europe from China in the seventeenth century and at that time the Europeans did not know what it was. Zinc was separated for the first time in England in AD 1680. Nāgārjuna, on the other hand, termed zinc as Kūtilaśaṁkāsaṃ ('the metal resembling tin'), which meant that he knew it was not tin but a different metal. In later centuries, zinc adopted new names like Jasada, Jasadāyaka or Yasada, clearly indicating its application in brass-making. (Yasada meant 'convener of success', probably in alchemical operations).

The alchemical texts written in the fourteenth and fifteenth centuries (e.g. *Dhātukriyā* and *Dhātumañjarī*) gave synonyms of zinc as Jasada, Yasadāyaka, Rupyabhrātru ('brother of silver'), Charmaka, Kharpara, Rasaka, etc. Nāgārjuna named calamine as Rasaka but he gave no separate name for its essence (i.e. zinc). This indicates the antiquity of zinc in India and also supports the belief that *Rasaratnākara* was written before zinc was recognized as a different metal and before separate names were given to it.

The verse in which an amalgam of mercury and gold was said to have been used for making an elixir, marked the shift of Indian alchemy from elixirs of plant origin to those based on mercury. This method was similar to the one adopted by Chinese alchemists in the second century AD. It was also similar to the method of preparing elixirs or 'Senthuram' in Tamil alchemical texts.

In the final few verses the author of *Rasaratnākara* gave the names of apparatuses used in alchemical processes—Śilāyantraṃ, Pāṣāṇayantraṃ, Bhūdharayantram, etc., in all 26 Yantras or pieces of apparatus. He also quoted the names of earlier alchemists like Sākaṅḍa, Māṅḍavya and Vaśiṣtha, indicating that alchemy was at an advanced state in Nāgārjuna's time.

Rasārṇava

After *Rasaratnākara* of Nāgārjuna, there appeared a number of alchemical treatises in the eleventh to twelfth century AD, namely, *Rasahṛdaya, Rasārṇava, Rasārṇavakalpa, Rasaprakāśasudhākara, Rasendracintāmaṇi,* etc. Among them, *Rasopaniṣad* and *Rasārṇava* were the largest consisting of about 2600 verses. The author of *Rasārṇava* appeared to be a Hindu of Śaiva cult. This text was written more systematically than *Rasaratnākara* of Nāgārjuna. It was subdivided into 18 chapters.

The first chapter introduced the philosophy of mercury and presented details of various rituals to be performed by the practitioner. The second chapter dealt with the selection and initiation of disciples. The third and the fourth ones described the various apparatuses used as well as the characteristic flames of a number of substances. Here, the author also describes the various kinds of fires (sources of heat) to be employed in the numerous chemical operations.

The fifth chapter was devoted to various medicinal plants, salts, acids, bases, etc. The chapters from sixth to ninth presented an account of all the metals and minerals along with their methods of extraction, purification and dissolution in respective solvents. The tenth chapter was devoted to mercury, its fixation and physical states and the cultivation operations performed on it. The particular operation which made mercury lose its volatile nature and become more reactive was termed as fixation or killing.

The author presented a detailed account of the methods of fixing mercury, using other metals, salts and plant products in the chapters eleven to fifteen. *Rasārṇava's* sixteenth, seventeenth and eighteenth chapters were important from the point of view of alchemy. Transmutation of metals was described in the sixteenth and seventeenth chapters whereas the eighteenth dealt with physiological alchemy or elixir-making. *Rasārṇava* was the first text of its kind in Indian alchemy, in which alchemy had been discussed fully and exhaustively. The later texts, with a few exceptions which used this format, were by no means as exhaustive. Other authors often quoted from *Rasārṇava*, either a verse or two or several verses, as seen in *Rasārṇavakalpa*. Considering these facts, *Rasārṇava* was undoubtedly the most prominent and widely read text on alchemy in the centuries after the twelfth.

Rasārṇavakalpa

Very few of the Rasāyana texts have been translated into English. B.V. Subbarayappa and Mira Roy have edited and translated the text *Rasārṇavakalpa*. It is part of a Tāntrik text entitled *Rūdrayamala*. *Rasārṇavakalpa* was perhaps a compilation of earlier texts made around the eleventh century AD. A part of this text was also found in *Rasārṇava* (verses 78-207 of *Rasārṇavakalpa*). Some other sections are also common to both, for example, Viṣodakakalpa, Candrodakakalpa and Śailodakakalpa (i.e. sections on poisonous-water, moon-water and mountain-water, respectively), with slight changes in their content. Some 40 plants are mentioned in this text.

Rasārṇavakalpa is esentially a text on transmutation of base metals into gold and silver. A few methods of elixir synthesis were also given. The text is arranged in a number of sections, named according to the particular plant used in the methods given in that section, rather than according to the metallurgical operations involved in them; for example:

1. Aparājitakalpa: a section on *Clitorea ternatoa*
2. Brahmadaṇḍikalpa: a section on *Lamprachaenium microcephalum*
3. Aśvagandhakalpa: a section on *Withania Somnifera*.

The number of plants mentioned in *Rasārṇavakalpa* is smaller than that in *Rasārṇava*. Certain substances of animal origin like goat's blood, pig's fat and earthworm excreta are not mentioned in *Rasārṇavakalpa*, but are found in the other text. Methods of transmutation and elixir synthesis in *Rasārṇavakalpa* were simpler with fewer ingredients, as compared to *Rasārṇava*. Certain poisonous substances like copper sulphate, ammonium chloride and borax are excluded from the edible elixirs of *Rasārṇavakalpa*. These facts suggested that *Rasārṇavakalpa* is a later text than *Rasārṇava*.

Rasopaniṣad

Rasopaniṣad, one of the largest Sanskrit treatises on alchemy, contained over 2,500 verses in its 18 chapters. It was probably part of a larger treatise entitled *Mahodadhi*, which is no longer extant. It was written around the eleventh or twelfth century AD in south India. Like other Sanskrit alchemical texts written around AD 1100, *Rasopaniṣad* primarily dealt with transmutation of metals and, to a small extent, with experiments relating to physical immortality. The language was Āyurvedic in nature, but it did not contain any Āyurvedic recipes as seen in later texts like *Rasaratnasamuccaya*.

Rasopaniṣad has also been translated into English. It stands apart from other alchemical texts like *Rasārṇava* in that it does not provide primary information on such subjects as the description of apparatuses or the 18 Saṁskāras (methods of cultivation) of mercury, etc. The author was more interested in alchemical experimentation and he divides the chapters according to the main chemical substance or reaction discussed in it. It was written more as a record of alchemical experiments than as an exhaustive book dealing with all the theoretical and experimental aspects of alchemy.

Plants, their various parts and products like juice and gum formed an integral part of alchemy in *Rasopaniṣad*. The study of plants and their applications in this treatise gives an idea of how extensively they were employed and how far the science of botany was developed at that time. Properties of plants like the acidic or alkaline nature of their extracts, other chemical constituents of various parts (e.g. dyes), or carbon content of their wood were responsible for their numerous applications in alchemy.

Rasopaniṣad, in its 18 chapters, has described an amazing number and variety of alchemical golds and silvers. It indicates the enormous nature of activity which the author had painstakingly elucidated. Alloys were made by either melting together two or more base metals or by diluting the noble metal with a baser one. Golden and silver-coloured amalgams were also made. A critical study of the text disclosed the author's knowledge about metals and metallurgy. A whole chapter is devoted to gold and silver making processes, using tin as the starting material. This indicated that some important facts about tin were known to the alchemists. For example, they knew that tin existed in two physical modifications, white and grey; that tin had a low melting point; that pure crystalline tin resembled silver; and that the addition of a little silver to pure tin inhibited the transformation of white tin to grey tin.

The twelfth chapter was entirely devoted to cleansing metal surfaces and removing tarnishes from copper and brass. These operations are considered essential even today before electroplating and enamelling in modern metallurgy. Medieval Indian alchemists also employed such methods, to obtain clean, lustrous metals before they were melted together to get homogeneous alloys.

The author of *Rasopaniṣad* employed a variety of crucibles in the alchemical and chemical operations he is engaged in. From the choice of crucibles he made, it is obvious that he had a basic knowledge of their construction, characteristics, and applications. Not only could he construct a variety of crucibles suited to particular chemical operations or to particular reaction mixtures, but he could also line them with different pastes to serve some specific function, for example, to supply acidic, basic or reducing atmospheres or to provide a non-absorbent coating.

Rasaratnasamuccaya of Vāgbhaṭṭa

Rasaratnasamuccaya written by Vāgbhaṭṭa in the fourteenth century AD marked the beginning of the iatrochemical period of Indian chemistry. This is a Buddhist text since the prayers are addressed to the principal of physicians, Bhaisajyaguru or Buddha, in the opening chapter. As in other alchemical treatises like *Rasārṇava*, the substances used are first divided into various categories, which formed chapters second to eighth. The succeeding chapters give details of apparatuses and chemicals such as acids, bases, oils, earths (ores), poisons and solvents.

The eleventh chapter of *Rasaratnasamuccaya* is devoted to purification, fixation and incineration of mercury. The rest of the text presented numerous medicinal preparations which are prescribed in the treatment of diseases and also for rejuvenation. A remarkable feature is that elixirs for longevity and immortality as well as transmutation of metals are totally absent in this text.

During the iatrochemical period a number of Rasāyanas were made using metals, non-metals and plant products. The tonic value of several minerals was recognized. If these substances were water insoluble, their soluble compounds were made. Also, colloidal solutions were made of sparingly soluble compounds. Thus the main aim was to bring the metals and non-metals into a solution form. The process was called Dṛti (melting or dissolution) and absorption of these dissolved materials into the body was called stabilization or Sthirikaraṇa. Bhasmikaraṇa (making of a calx) was also discovered for a number of substances. During the iatrochemical period (i.e. after the thirteenth century AD), experiments were performed to find drugs with better therapeutic properties. More and more research was directed towards finding efficacious drugs in solution or calx form. Mercury was often used with the above substances, if found to enhance the therapeutic value of the drugs. Collection of the volatile essence or Arka of drugs was a development of this period. Drugs like Opium, Akkalkarā, Khurāsāni, Ajawain, Jamālgoṭā, Jāyaphala, Mājuphala, Gulāb and Bhāng were found only after the fourteenth century AD. These words could, therefore, be used as keys to determine the date of writing of a text.

In this way, a large number of treatises, totally devoted to medicine were written in the later centuries. Ancient works by Caraka, Suśruta and Vāgbhaṭa (e.g. *Aṣṭāṅghṛdaya, Aṣṭāṅghṛdaya Saṁhitā*) were still referred to a number of compendia in which extracts from different texts were compiled together, were written in the centuries between the fifteenth and seventeenth (e.g. *Rasendrasārasaṃgraha)*.

In the later part of the iatrochemical period also a great many number of texts were written. They are characterized by the mention of calomel and chobschini (China root or smilex china) for treatment of *Firdngdroga* or syphillis. They also mention a number of mineral acids and their mixtures under names like *sankhadiavaka* or *Dahajala* (meaning 'solvent for conch shell' and 'burning water' repectively). *Rasamañjari* of Satinātha, *Rasaranjana, Gandhakakalpa* are of this period.

Rasapradīpa is one of the standard works of the late iatrochemical period. It mentions calomel and chobchini as a remedy for syphillis. It is generally accepted that Chinese traders in Goa made this drug known to the Portuguese in about AD 1535. Hence, it was surmized that *Rasapradīpa* was a product of the late sixteenth century. Another feature of this work was that it gave a recipe for producing mineral acids by distilling a mixture of alum, sal-ammoniac, saltpetre and sulphur. With this recipe, *Rasapradīpa* undoubtedly became a landmark in the history of Indian chemistry. *Svarṇatantra*, another text of this period, described a mixture of mineral acids which the author named as *Śaṅkhadrāvaka.* Here an account of only a few texts has been presented to give an idea of the nature of such texts. From their contents it should be possible to assess the contribution of Indian alchemy to chemistry in general.

Mercury was known and was used in the extraction of gold by amalgamation or in amalgamation gilding since ancient times. But the alchemists made an extensive study of mercury and its compounds and the processes for purifying or killing it. Metallurgical operations carried out with the objective of making gold enabled the alchemists to accumulate new chemical data. Alloys with varying percentage compositions were synthesized. Variations in physical properties due to variation in percentage composition were observed and noted. Control of temperature was vital in these pyro-techniques, and was achieved by using different furnaces and fuels.

Again, there were chance discoveries, such as that of the flame test for identification of ores; also of the volatile, sublime or explosive nature of certain substances.

Discovery of mineral acids could be safely regarded as the greatest contribution of alchemy to chemistry. The different waters with names like 'mountain water', 'poisonous water' and 'moon water' of the Sanskrit texts were actually mineral acids. The alchemists discovered them during their experimentation. They were found to have a number of applications in alchemical operations. These acids served different purposes, of dissolving metals, cleansing metal-surfaces, fixing mercury, or providing an acidic medium for carrying out certain reactions. These mineral acids were stored in the hollow of a dried gourd, since they could not be stored in metallic containers because of their corrosive nature. Physical and chemical properties of these acids were described in a number of verses in such texts as *Rasārṇava* and *Rasārṇavakalpa.* The verse in *Rasaratnasamuccaya,* which describes the preparation of the 'essence of alum' or sulphuric acid, goes as follows:

> Turvari or alum is purified when immersed in Kānjika (or the fermented rice water or crude vinegar) for three days. It (alum) when rubbed with Kṣārāmla (acidic salt) and heated certainly gives its essence.

Here Kṣārāmla or acidic salt is ferrous sulphate or Kāsisa, which when heated with alum produces sulphuric acid. Hence the earlier belief that mineral acids were not known in India until the sixteenth century AD was not correct. This fact is of relevance, since the early chemical industries of Europe were based on synthesis and application of mineral acids, thus giving impetus to the eighteenth century industrial revolution in European countries.

No doubt the earlier attempts at transmutation of base metals into gold proved to be futile exercises in the light of modern atomic theory, yet the enterprise of the medieval alchemists, though they never achieved what they were looking for, helped accumulate considerable useful data. These data, when studied devoid of their superstitious and religious content, disclosed basic facts and, with meticulous experimentation, led to correct ideas about the nature of elements, properties of matter, theories of chemical combination, and later even to the modern atomic theory. It is this evolutionary development that triggered the chemical revolution of the eighteenth century.

A great many alchemical and iatrochemical texts remain unexplored in a large number of oriental collections. Most of them are in manuscript form. Only when all these are explored and their contents made known, then one could judge the true nature of these activities and the developments in theoretical and factual knowledge that took place through them. A detailed study of a few of these texts has brought to light some interesting facts which are mentioned above. Critical studies of selected treatises and archaeo-chemical analyses of the finds of further explorations will no doubt yield a clearer picture.

Thus with the decline of the Rasaśāstra school of alchemy there emerged a school of 'Rasacikitsā', a fruitful combination of Āyurvedic and Rasāyana medicines.

The aforesaid account of Indian alchemy shows that it was fundamentally similar to alchemy practiced all over the medieval world, with its ideas of gold-making and elixir-of-life, originating from the philosophy of mercury. Still, Indian alchemy had its own special features. The philosophy of Śiva and Gauri being the originators of alchemy, mercury and sulphur being their essences, extensive use of plants inherited from Āyurvedic practices and finally a fruitful union of Āyurvedic medicines with those of mercury form the chief characteristics of alchemy and iatrochemistry in medieval India.

For lack of literary tradition it is not possible to exactly pin-point the origin of alchemy or to unearth the factors responsible for transition of medicines prepared from plants to the mercurial ones. The Buddhists seems to have played a key role in this transition. Either they were responsible for originating the mercury-based alchemy through their love for medicines and concern for the poor and the sick, or they introduced the mercurial medicines into India from China, during their long intercourse with that country between the second and tenth centuries AD.

In India, the three practices of metallurgy, alchemy and medicine were interlinked and inter-dependent. Alchemy developed considerably in medieval period by borrowing from the earlier metallurgical, botanical and medical knowledge. Also with its new experiences alchemy further expanded its boundaries.

Transmission of Scientific Ideas

India had contacts with its neighbouring countries from times immemorial. Glazed steatite seals of the Harappan type were found in Ur and other cities, and cylindrical seals engraved with elephants which resembled the Indus style were recovered from Eshnunna. Such archaeological evidences suggested that India had relations with western Asia in the third millennium BC. It has been said that modern western civilization is indebted to the Sumerians. Prehistoric contacts between India and Sumer suggest Indian contribution from the earliest times.

There was a flourishing Indo-Roman trade in the first century BC. Sugar, pepper, indigo, cardamom, precious stones, etc. were exported from south India. Mineral and metal products were also exported. Apart from commerce and trade, there ensued a transmission of philosophical, scientific and technological ideas between India and its neighbours. The advanced knowledge of Indian scholars in disciplines like mathematics, astronomy and medicine impressed the rulers of neighbouring countries so much that they began to encourage translation of important Indian treatises into their own languages. This occurred specially in Persia and China, and Indian thought and philosophies were well known among Arabs and Greeks alike. Indian medical knowledge was held in high esteem. Indian plant products were used in various prescriptions even by the Greek authorities.

In his *De medicina,* Celsus described lithotomy, a surgical operation developed and practiced by the Hindus and described in *Suṣruta Saṁhitā.*

Arabs knew about Āyurveda and Indian medicine in the ninth century AD. The Caliph Hārūn-ar-Rashīd (AD 786-809) was cured of a chronic illness by an Indian physician named Manka, who was specially invited to Baghdad for this purpose. Several Āyurvedic works were translated into Arabic by order of the ruler of the time. Court physicians wrote about the Indian system of medicine, and the names of Indian physicians who visited Baghdad were also noted down.

One such court physician of the ninth century AD, Ali Ibn Rabban al-Tabarī wrote *Firdaus-al-Hikmah* ('Paradise of Wisdom') in the seventh part of which he gave a summary of Indian medicines. He used *Caraka Saṁhitā, Suṣruta Saṁhitā, Mādhavanidāna* and *Aṣṭāṅgahṛdaya* as sources to write his account. He categorically stated that he included the Indian system in his work because of its excellence.

Many manuscript libraries of the world also provide lists of Sanskrit works which have been translated into Persian from AD 1000 to 1800. These include works on Hindu sciences like astronomy, mathematics, cosmology, medicine, magic and occult sciences; they may include some works on alchemy as well. It is worthwhile to note that the renowned physician Jabir bin Hayyan lived during this period.

In the year AD 771 an Indian cultural mission reached Baghdad and presented a copy of *Brahma Siddhānta* to Caliph Al Mansur, who ordered the court astronomer Al-Fazari to translate it into Arabic. *Brahma Siddhānta* exercised a lasting influence on the Muslim science of stars. M.Y. Mirza quoted Arabic sources to state that these influences took the form of a definite school of astronomy called Al Sindhind (Siddhānta). Various Sanskrit works were translated into Arabic as a part of this movement. It would be interesting to trace Indian scientific heritage in the works of Muslim scientists and philosophers of the period.

India and China had contacts since the ancient times. After Buddhism was introduced to China in the early centuries of the Christian era, exchange of philosophical and scientific ideas followed. Hundred of texts on philosophical and secular subjects were translated by the Buddhists into Chinese. Numerous Chinese texts written during the Tang dynasty (AD 618-916) referred to Indian scholars and their knowledge of science.

One of the earliest references was found in a bibliography of the Sui dynasty. It gave a list of Indian scientific books translated into Chinese. Some medical works attributed to

Nāgārjuna are still extant in a medieval collection on such works. They are on topics ranging from perfume-making to printing and ophthalmology.

A certain paragraph in Chinese text, *Shih Yao Erh Ya* by Mei Biao referred to the visit of a Buddhist monk to China in AD 664 and to his knowledge of saltpetre, its extraction and applications. This Buddhist monk also knew about the flame test for examining saltpetre. The book also described how knowledge regarding mineral acids was transmitted to China through a Brahmin scholar, who was brought to the Chinese court along with an Indian prisoner prince in the seventh century AD.

These instances clearly indicate the extent of transmission of Indian sciences and techniques to neighbouring culture areas during the medieval period.

V. THE PRE-MODERN PERIOD (AD 1600-1900)

During the period AD 1300-1600, chemistry developed mainly in the form of alchemy and iatro-chemistry. Chemical arts and crafts continued to flourish. From the early seventeenth century onward a marked decline in alchemical writings was observed. Alchemy which was zealously practiced since the beginning of the Tāntrik period, lost its flavour. This was possibly on account of the realization that alchemy could not deliver the goods it promised, namely synthesis of noble metals. Extensive experimentation over a millennia proved beyond doubt that it was not possible to synthesize gold and silver by means of pyrotechniques adopted by alchemy.

It was a period of the ascendancy of iatrochemistry. More and more mercurial medicines were incorporated in the traditional system and many of them proved efficacious, as in the case of calomel. The new works in this period were commentaries on the old treatises, their translations into regional languages with explanatory notes; or compilation of selected verses relating to a particular topic, from various standard texts. Dictionaries and encyclopaedias were also compiled. Some of the texts, which were basically Āyurvedic in nature, contained some chapters on mercury and other metals. Some references to alchemy were also noticed in these texts.

Dravyaguṇasataśloki of Trimalla Bhaṭṭa, a seventeenth century text, was a work on Āyurvedic materia medica with its last section devoted to metals and mercury. One text named *Rasarājakalpalakṣmi* has explanatory notes in Marathi. Another work of the early eighteenth century, namely *Śivatatvaratnākara* of Keladi Basavarāja, was an elaborate encyclopaedic work on metals, minerals, their uses and effects when combined with other substances. This work also gave various methods for conversion of base metals into gold. Moreover, it described a chemical laboratory and the proper arrangement of articles in it. This was a new feature for such a texts. *Āyurvedaprakāśa* was yet another similar work by Mādhava Upādhyāya. It was composed in the beginning of the eighteenth century AD. It seemed that the author was an expert in Āyurveda as well as alchemy.

After the decline of alchemy, iatrochemistry probably reached a steady state over the next 150-200 years and then it, too, declined due to the introduction and later acceptance of western medicine in the twentieth century. During the period of stagnation, Āyurveda continued to answer the medical needs of the people, without significant progress or incorporation of new ideas or drugs. The pharmaceutical industry based on Āyurveda also continued to exist and then slowly declined.

The chemical arts and crafts, which served the people over two millennia, for example pottery, brick making, glass, ceramics and ornament-making, continued to flourish during this period. The story was different for some of the arts though; for the first time they began to encounter competition from the superior and cheaper products of the industrialized nations. They were mainly industries like dyeing, iron and steel. Some of the industries just didn't take off, for example the manufacture of mineral acids. Although mineral acids were separated in the sixteenth century AD, as witnessed in the later alchemical texts, they hardly had any applications specially after the decline of the native small-scale industries.

There was a large time-gap between the giving up of old methods of production of certain chemicals (e.g. alkalies and acidic extracts) and the adoption of newer methods based on modern chemical ideas. After the old ones became obsolete, it took about 100-150 years for the Indians to learn and adopt new techniques. This was the time when foreign products poured in. Thus, indigenous units using traditional techniques generally declined, more as a result of adverse policies of the rulers, than due to decline in demand. The manufacturing power of India was slowly crushed and people fell back more and more on agriculture.

Geography, geology and surveying were the first sciences to be introduced to India by the British, because they were more interested in having an accurate knowledge of the geography and natural resources of the conquered territory. Similarly, railways in India resulted from the declining market for British iron and steel in Europe and the USA. The necessity for speeding up the transport of raw materials like iron-ore to the ports was no less responsible. Manufactured iron and steel products from Britain found an assured market in the growing demands of Indian railways, which the indigenous small-scale industry could not fulfil.

The Indian dye industry met with a similar fate. It survived until the mid-nineteenth century. Indian dyes were superior in quality and low-priced and they brought considerable returns to the European trading companies. Indigo plantation was, therefore, supported by the East India Company till the beginning of the nineteenth century. The first magenta dye was prepared by AD 1856 and was imported by a Bombay firm. The next to be introduced to the Indian market was synthetic alizarin dye. Around 1880 Indigo was cultivated over some 1,11,000 acres in Saran, Champaran and Monghyr districts together. The East India Company earned over £ 100,000 per year. In the year 1631, about 333,000 lbs of indigo were exported to Holland. Synthetic indigo was discovered by Huemann in 1890 and, as a consequence, indigo cultivation in India suffered and finally stopped. Earlier, in the sixteenth-seventeenth centuries, indigo was prohibited all over the European continent for over a century, to give a boost to the European product, namely Woad (*Isatic Tinctoria*). Later, in the year 1860, synthetic alizarin was made by Graebe & Liebermann, mauvine by Perkin (1873), and congo red by Bottinger (1883). Thus, the synthetic dyes completely overtook the natural dyes. This is a classic example of how adverse policies and lack of scientific research could harm native industries.

Although India had close contacts with the Europeans in the formative years of modern science (i.e. in the seventeenth, eighteenth and nineteenth centuries) modern science was late in appearing on the Indian scene, i.e. only in the later part of the nineteenth century. By the mid-nineteenth century European scientists started coming to India. They were medical men, engineers, surveyors and also chemists. They were the ones who introduced India and some intelligent young Indians to modern science. Through their works, scientific research became known to the Indians, both as a tool of investigation into natural phenomena and also as a means for development of useful technologies. As already mentioned, surveying, geology and geography were the first modern sciences to be introduced to India. Civil engineering and medicine came next. Modern chemistry was the last to enter the scene. A science college was established in Calcutta in 1814. The study of chemistry was first introduced in the Presidency College of Calcutta in 1872 followed by post-graduate teaching in chemistry in 1886.

Earlier, chemical researches were carried out by British scientists, who were serving in India in various capacities, like Robert Blake and David Waldie who founded the Cossipore Chemical Works at Kossipur in Bengal. W.B. Shughnessy was a chemical examiner with the

Government of Bengal and professor of chemistry at Medical College, Calcutta. He was also Deputy Assay Master in the Calcutta Mint. During his long stay in India from 1833 to 1860 he conducted researches in toxicology, chemistry, metallurgy, galvanic electricity and finally constructed the first telegraph line between Calcutta and Diamond Harbour.

The Indian Association for Cultivation of Sciences was established in 1876. Early chemists like Chunilal Bose and P.C. Ray were actively associated with it. P.C. Ray was well aware and proud of the fact that Indians had made considerable progress in the field of chemistry during the ancient and medieval periods, as was evident from his two volumes on *History of Hindu Chemistry*. As regards his modern chemical research, around 1896 Ray studied the stabilities of metallic nitrites and hyponitrites and the action of nitric acid on metals. After Ray, Chandra Bhusan Bhaduri and Jyoti Bhusan Bhaduri were the ones who conducted significant researches in the field of inorganic chemistry. They studied complex inorganic salts like copper-alkali ferrocyanide and sodium silver thiosulphate and the constitution of drugs like Andrographis penuculata, chlorates and chlorites, and also mercurous chloride which on decomposition gave chlorine gas. Seeds of research in physical chemistry were sowed by R.D. Phookan who studied the rates of evaporation of bodies in the atmosphere at different densities. A campaign was also started for the restoration of Āyurvedic medicine.

Thus, inspired by the new scientific spirit of the period and by works of the early European scientists who resided in India and pursued their researches, a band of young Indian scientists started taking keen interest in modern scientific research activities. At the same time, they felt the need for native chemical industries, based on modern lines. P.C. Ray established the Bengal Chemical & Pharmaceutical Works Ltd. in Calcutta; J.K. Gajjar with the help of Kotibhaskar and Amin established the Alembic Chemical Works in 1905 at Baroda; and Vakil in 1937 established the alkali industry under Tata's patronage and Tata Chemicals Ltd. came into existence. Thus was the Indian chemical industry established and it continued to grow with a slow but steady pace in the twentieth century.

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CHAPTER VI

Pre-Telescopic Astronomy in India

Rajesh Kochhar

I. INTRODUCTION

Ever since human beings learnt to walk upright, they have looked at the sky and wondered. The sky has remained the same, but the human perception of it has changed continually. This changing perception mirrors not only the history of astronomy, but also of human civilization itself.

Modern astronomy tells us that the Universe is a collection of a large number of galaxies, each of which contains hundreds of billions of stars. The Sun is an average star on the outskirts of our galaxy, called the Milky Way Galaxy. Around the Sun go nine planets which, arranged in the order of increasing heliocentric distance, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The last three are not visible to the unaided eye and were discovered using telescopes. In addition, the solar system contains very small planetary bodies, called the asteroids, mostly confined within the orbits of Jupiter and Mars. Finally, there are the comets, small 'ice balls' which develop spectacular tails when their orbits bring them close to the Sun.

The ancient man's perception of the Universe was based on 'seeing is believing'. The Earth was assumed to be the center of the Universe. Around it revolved the seven geocentric planets: Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn, arranged in order of increasing geocentric distance. Beyond Saturn lay the unchanging fixed starts, stitched on the dark tapestry of the night sky. In the ancient Indian scheme of things, stars were observed not for their own sake but as a backdrop for the planetary motions. Such stars and star groups were called Nakṣatras.

The ancient planetary model was correct only in one detail: the Moon went around the Earth. Though physically wrong, the geocentric model could still provide correct orbital elements. The Earth's orbital period around the Sun was attributed to the Sun's virtual orbit around the Earth, so that the Sun was said to take a year to go around the Earth. When the outer planets went around the Sun, they went around the Earth as well. Therefore, their geocentric and heliocentric periods were the same. In the case of the inner planets, Mercury and Venus, the geocentric theory replaced the planet with a mathematical artifact called Sigrocca. It was correctly assumed in ancient times that a longer orbital period implied greater geocentric distance for the planet. Thus the planets were correctly ordered according to their geocentric distance. (Kepler's laws tell us that the heliocentric planetary distance is not linearly proportional to the orbital period P, but to $P^{\frac{2}{3}}$.) While discussing ancient developments, it is convenient to use the geocentric terminology which conveys the flavour of the times.

It would be meaningless to speculate as to when the (geocentric) planets were discovered. The Sun and the Moon were undoubtedly a part of the human evolutionary process itself; the other planets would have surely been noticed way back in time.

India's astronomical tradition, as indeed the whole culture, had been fashioned by geography. Lofty mountains in the north and the oceans in the south made India into nature's protectorate. At the same time, the north-western mountain passes permitted inflow of people and ideas. Accordingly, India took to agriculture and settled life very early, maintained an unbroken cultural tradition, and reinforced it by periodic intellectual inputs from other cultural areas. The unique combination of antiquity, continuity and unselfconscious interaction with the outside world on equal terms was India's hallmark, till the age-old pattern was disrupted by the European arrival by sea.

Indian pre-history began with the vast Harappan, or the Greater Indus Valley, civilization which represented a cultural continuum extending from *c.*7000 BC to *c.*1400 BC. The high point of this civilization was the mature, or the urban, Harappan phase (*c.*2500-*c.*2000 BC), characterized by well-planned cities, extensive external trade, manufacture of artistic seals, and development of Harappan script. One of the seals shows a boat and a crow, which no doubt was taken along to help spot land. Since maritime trade was an important part of the Harappan economy, it was likely that astronomy was used as a navigational aid. Many Harappan cities were aligned along cardinal directions, but Dholavira in Kutch showed a four-degree tilt. Unfortunately, at the current level of knowledge, it is not possible to say anything about the state of astronomy in the Harappan times.

II. THE VEDIC AGE

Our starting point in regard to astronomy in ancient India could only be *Ṛgveda,* which was a compilation of 1028 hymns composed by a large number of authors over many generations. It is generally agreed on linguistic grounds that the youngest portions of *Ṛgveda* are not later than *c.* 1000 BC.

Vedic Texts

Ṛgveda stands at the head of the corpus of Vedic texts which includes, in a rough order of decreasing antiquity, four Vedic Saṁhitās: Brāhmaṇās, Āraṇyakas, Upaniṣads and Vedāṅgas. In this context, when text A is said to be older than text B, it means that A was closed earlier than B, so that the latest portions of B are later than the latest portions of A. A younger text, however, may contain portions that are very old. The value of the Vedic texts lies in the fact that, once closed, their contents were preserved unchanged. This is in contrast to the Purāṇas and the epics *Rāmāyaṇa* and *Mahābhārata,* which were often recast to fulfil contemporaneous needs, so that their contents cannot be confidently dated.

According to *Ṛgveda*: 10.72.7, the Sun sank into the ocean every evening from where it was pulled out by the gods for rising the next morning. *Ṛgveda*: 10.85.19 commented on the waxing and waning of the moon, while *Ṛgveda:* 10.161.4 referred to a year as represented by the return of the seasons: 'Do live and grow for a hundred autumns, for a hundred winters, and for a hundred springs.' The Ṛgvedic year consisted of 12 months, each month of 30 days, giving a total of 360 days to a year (*Ṛgveda*: 1.164.48). *Ṛgveda* repeatedly referred to Bṛhaspati as 'the lord of the prayers'. It was not clear whether Bṛhaspati's identification with Jupiter had already been made or was a later development. In Vedic literature Bṛhaspati was called the 'regent of the Nakṣatra Tiṣya' (Delta Cancri); *Ṛgveda*: 10.123 mentioned Vena, and *Ṛgveda*:

3.32.2 and 9.46.4 mentioned Śukra. There is however no reason to suppose that here Venus is meant.

The term Graha ('seizing') first occurred in *Śatapatha Brāhmaṇa*: 4.6.5.1 to refer to the Sun, probably not in the later sense of a planet, but to denote a power that exercised magical influence. Use of Graha in the sense of a planet occurred in later literature, for example, in the *Maitrayani Upaniṣad*. In *Taittirīya Āraṇyaka* (1.7), 'sapta-sūryaḥ' (seven suns) probably means the seven planets.

While the astronomical references in the *Ṛgveda* and other major Vedic texts were sporadic and desultory, there existed an ancient, exclusively astronomical, text called *Vedāṅga Jyotiṣa*, ('Astronomy as part of the Vedas'). This text had two recensions: one attached to the *Ṛgveda*, the other to *Yajurveda*. The *Ṛgvedic Jyotiṣa* consisted of only 36 verses, 30 of which were repeated in *Yajurvedic Jyotiṣa*, though not in the same order; to these, the *Yajurvedic Jyotiṣa* added 13 verses of its own, bringing its own total to 43. Thus, there were in all 49 verses in the *Vedāṅga Jyotiṣa* taken as a whole. *Vedāṅga Jyotiṣa* was the most neglected part of the Vedic literature. Its serious study was taken up barely 100 years ago under European auspices. To date, only about 36 of the total of 49 verses have been deciphered.

The authorship of the *Ṛgvedic Jyotiṣa* was attributed to Lagadha, about whom nothing else is known. The book contained an observational statement that winter solstice took place at the star group Śṛavistha (Alpha Delphini). If this statement was taken at face value, it could be dated *c.* 1400 BC on the basis of the phenomenon of precession of the equinoxes. Since we do not know the accuracy of the above observation, this date should be considered merely indicative.

The *Vedāṅga Jyotiṣa* calendar used both the Sun and the Moon as time-keepers. As we know, a year consists of 365 days, while a month, defined as the period from one new (or full) moon to the next, contains 29.5 days. A solar year thus can never contain an integral number of lunar months. Twelve months with their 354 days fall short of a year by 11 days. A lunar-solar year must consist of 12 or 13 lunar months. The key question is when to add the extra (intercalary) month.

The *Vedāṅga Jyotiṣa* added two intercalary months in a period of five years, which thus contained 62 lunar months or 1830 days. Therefore, the Vedāṅga calendar, with an average year length of 366 days, accumulated a rather large error of four days in five years.

Vedic Yuga System

For later reference, let us examine a theoretical artifact of the Vedic times, namely, the yuga system. It did not seem to have had any scientific connotation, at least to begin with. The basic sense of yuga was not a fixed unit of time, but any time span that could be associated with a recurring phenomenon. The word occurs at a number of places in *Ṛgveda*, probably standing for different time periods.

In *Ṛgveda*: 6.85, Agni, the god of fire, was requested to give riches and success to 'us who offer new words of praise to thee for the sake of sacrifices in each yuga'. *Ṛgveda*: 10.97.1 talked of herbs 'created by gods in three yugas before'. These references did not provide any clues to the meaning of a yuga. *Ṛgveda*: 1.158.6 referred to Dirghātamās 'having grown old in the tenth yuga'. Here, obviously, yuga was a fraction of human life, may be five or ten years. *Vedāṅga Jyotiṣa*, as already seen, seemed to imply a five-year yuga. *Atharvaveda* mentioned, in order, 100 years, an ayuta (10,000 years) and then two, three, and four yugas. This suggested that a yuga here probably meant 10,000 years.

The terms Kali, Dvāpara, Tretā and Kṛta were mentioned in the Vedic literature as the designation of throw of dice, marked 4, 3, 2 and 1. Four ages, Puṣya, Dvāpara, Khara and Kṛta, were mentioned in the later portions of *Ṣaḍvimśa Brāhmaṇa*, while Dvāpara was mentioned in the *Gopatha Brāhmaṇa*. Interestingly, the Brāhmaṇa literature considered Kṛta to be something good and the others increasingly inferior, with Kali the worst. It was however not clear whether the reference here was to a time-span or throw of dice.

Yaska's etymological text *Nirukta* (*c.*400 BC) defined Brahma's day as equal to 1000 yugas, without saying what a yuga was. Brahma's day was followed by his night of the same duration during which he slept. Brahma's day and night together made his Ahorātra. To get an idea of the actual years involved in these units, we must turn to *Manusmṛti*: 1.68-86, which in its opening chapter described the yuga system in detail. The system was based on scaling the terrestrial phenomena to divine proportions by making suitable assumptions. *Ṛgveda* used a year or a Samvatsāra of 360 days. *Taittirīya Brāhmaṇa* defined this year as equal to a day of the gods, so that a divine year (Dyr) consisted of 360 (human) years. The divine year was used as the building block for the yuga system.

Manusmṛti defined a unit of time called Mahāyuga or caturyuga made up of four yugas—Kṛta, Tretā, Dvāpara, and Kali—with lengths in the ratio 1:2:3:4. The Kaliyuga was thus the shortest. It comprised a core period of 1000 Dyr preceded and followed by a transitional period of 100 Dyr each, so that Kaliyuga in all had 1200 Dyr. The Mahāyuga then contained $1200 \times (4+3+2+1)$ or 12000 divine years. Multiplying it by 360 gave the number of human years in a *Mahāyuga*. Thus 1 Mahāyuga = 43,20,000 years.

Next, 1000 Mahāyugas are set equal to a Brahma's day. However, the neat figure of 1000 is arrived at in a complicated manner. To see this, let us denote a Mahāyuga by 'm' and recall that in a Mahāyuga, a Kṛtayuga, 'k', accounts for four parts in 10, so that $k = 2m/5$ or $m = 5k/2$.

$$
\begin{aligned}
\text{1 Brahma's day} &= 1000m \\
&= 994m + 6m \\
&= 994m + 15k \\
&= 14 \times 71m + 14k + k \\
&= k + 14\,(71m + k)
\end{aligned}
$$

Let us now define 71 Mahāyugas (71m) as a Manvantra (Manu's interval), or Manu for short. Then, the above equation can be expressed in words as follows: 'A Brahma's day consists of a dawn equal to a Kṛtayuga followed by 14 Manvantras to each of which is appended a twilight also equal to a Kṛtayuga.' The scheme can be continued to build Brahma's chronology. His Ahorātra would contain 2000 Mahāyugas. A total of 360 Ahorātras would make his one year, 100 of which his life. This scheme was repeated in the Purāṇas and *Mahābhārata*.

The concept of a Mahāyuga and a Brahma's day was adopted by the later-day mathematical astronomers, with one minor change in that Brahma's day was given the non-denominational designation Kalpa. The term Kalpa did not figure in the Vedic texts but was mentioned in the *Mahābhārata* as a unit of time.

In recent years, Kalpa was noticed by modern-day cosmologists, because the estimated 'age' of the Universe (the Hubble time) at 10-12 billion years turned out to be of the same order of magnitude as a Kalpa (4.32 billion years). Ancient Indians were perhaps the only ones to have conceptualized such large numbers, even though the context was unphysical.

The rather crude Sun and Moon-oriented astronomy of the Vedāṅga eventually made way for the mathematically rigorous planetary astronomy of the *Siddhāntas*. (A Siddhānta, literally meaning 'proven in the end', was the name given to the astronomical texts of the period.) The transition from the Vedāṅga to the Siddhāntic astronomy was made possible as a result of interaction with central and west Asia which, in turn, had been brought into contact with Greece in the post-Alexandrian period. This is most easily understood from an examination of calendrical references in inscriptions.

III. EVOLUTION OF THE CALENDRICAL SYSTEM

The oldest inscriptions in India, after the Harappan period, are the edicts of Aśoka put up during his reign (273-236 BC). These inscriptions are in Prākrt language and Brāhmi script. They used a Vedāṅga calendar: The years were counted from the king's coronation; no continuous era starting from a fixed point was used. Within a year, time was reckoned in three seasons of four months each. Each month was divided into two halves (Pakṣas). The month was lunar and Pūrṇimanta—that is, it ended with full moon. Within a month, days were reckoned by the Tithī, meaning the period from moon-set to moon-set during the bright half, and from moon-rise to moon-rise during the dark half. (Division of a lunar month into 30 Tithīs came later). The days were named after the Nakṣatras. The Vedāṅga calendar continued to be used by the successors of the Mauryas, that is, the Sungas and the Kanvas (186 BC-AD 45) and the Satavāhanas (AD 100).

The Luni-solar Calender

While the Indians were merely counting regnal years, beginning all over again when the new king took over, era-reckoning had been in use in Babylon since 747 BC. In 312 BC, the Seleucidan era was introduced to mark the accession to power in Babylon of Alexander's successor Seleucus. It seems reasonably certain that a mathematically accurate luni-solar calendar, based on astronomical knowledge, was first evolved in Seleucidan Babylon between 300 BC and 200 BC by Chaldean astronomers. The Chaldeans flourished between seventh century BC and third century AD in Mesopotamia (present-day Iraq). In this system, years were counted continuously. The year began with the lunar month of Nisan, which was to start on a date within a month of the spring equinox (corresponding to Vaiśākha). Alternatively, the year could commence with the Greek month of Dios which was to begin within a month of the autumn equinox (corresponding to Kārtika). The year was kept in phase with the seasons by adding seven lunar months in a period of 19 years.

It was this calendrical system which slowly penetrated India. The first era to be introduced in India was the Śaka era, brought in by the Śakas (known to the Greeks as Scythians) who arrived from central Asia. The Śaka era was believed to have originally started in 123 BC. In the year 201 of this era, that is in AD 78, Kaniṣka subtracted 200 from this number to arrive at the first year of the Śaka era as we know it.

We may, at this juncture, comment on the widely used Vikrama era, which according to legend was founded in 57 BC by king Vikrama of Ujjain to commemorate his victory over the Śaka raiders. The legend has no historical basis. The earliest mention of the Vikrama era was found in an inscription of one king Jaikadeva who ruled near Okhamandal in Kathiawar. The inscription was dated 794 of Vikrama era, or AD 737. A subsequent inscription, dated 795 Vikrama era called this era the era of the lords of Malava. Tracing back, we find that Malavagana era was used during AD 405-532 by a royal dynasty at Mandasor in Rajasthan, which was the feudatory of the imperial Guptas (AD 319-550). The era was called not only the era of the Malavas but also the Kṛta era. (The significance of this name is not known). A number if inscriptions dated in Kṛta era have been found in Rajasthan, the earliest going back to AD 225.

It thus seems that the earliest name of the era was the Kṛta. During AD 405-542, it came to be known as the era of the Malavas. Its association with Vikrama was first found in AD 737. Its early use was confined to Kathiawar and Rajasthan. In about AD 824, When the Gurjara-Pratihāras coming from Rajasthan conquered the city of Kannauj, they brought the Vikrama era with them. It became current in the whole of north India, except the eastern region, and was used by all the Rajput dynasties of medieval times.

The only historical king Vikramāditya, who was known to have crushed the Śaka power at Ujjain, was king Candragupta-II of the Gupta dynasty (*c.* AD 395). All the Gupta kings.

Samudragupta onwards, used Āditya as a title, many of them calling themselves Vikramāditya. In their inscriptions they used the Gupta era, which commemorated the foundation of their empire in AD 319. While the connection of the Vikrama era with Vikrama remains a puzzle, there could be no doubt that it had no physical connection with its starting point of 57 BC, which must have been arrived by back calculation. (Similarly, when the Julian calendar was Christianized in about AD 580, it was decided to begin the era with what was believed to be the year of Christ's birth. It was later shown that Christ was born not in the zero year of his era, but in the year 4 BC).

There were two other concepts of Mesopotamian origin that were incorporated into the Indian astronomical system: seven-day week and zodiacal signs. Both were unknown to the Vedic texts and did not figure in *Mahābhārata.*

Seven-day Week

The credit for originating the seven-day week, independent of the month or year, was generally given to the Chaldeans, who identified each planet with a god. Thus Saturn was identified with Ninim (god of pestilence and misery); Jupiter with Marduk (king of gods); Mars with Nergal (god of war); Sun with Shamash (goddess of fertility); Mercury with Nabu (god of writing); and the Moon with Sin (god of agriculture).

It is obvious that the week was given seven days in honour of the seven planetary gods. What is not so obvious is the order in which they appear. The day was divided into 24 hours. Each of the seven gods was supposed to keep watch on the world for one hour by rotation. The day was named after the god who was in-charge of the first hour. On day one the first hour was assigned to Saturn, the farthest of the planets, and the day was named Saturday. The hours were then assigned to the seven gods by rotation. Clearly then, Saturn would be the regent of the 1st, 8th, 15th and 22nd hours. The 23rd hour would go to Jupiter, and the 24th to Mars. The next god in line would be the Sun, who would get the first hour of the next day, which would therefore be called Sunday. The process can be repeated to obtain the weekdays in the order we are familiar with today.

The procedure can be easily understood from the accompanying diagram (Fig. 1). Choose a planet and name the day after it. Proceed along the sequence of decreasing geocentric distance and skip two names. The third planet is the one lending its name to the next day.

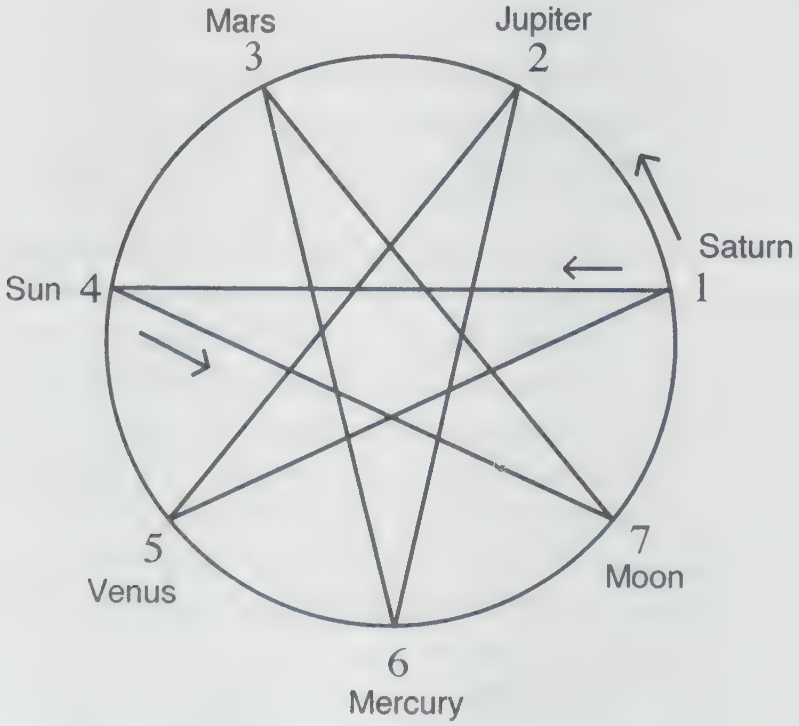

Fig. 1 The ordering of weekdays.

The Greeks were in touch with Mesopotamia as early as the sixth and fifth centuries BC. The contacts increased and extended further east into north-west India as result of Alexander's campaigns. A Chaldean priest, Berossus, in about 270 BC translated Chaldean astronomical works into Greek. It is certain that the seven-day week was transmitted to the rest of the world by the Greeks. Significantly, the weekdays figure in Indian inscriptions only from AD 484.

It is tempting to speculate on the grounds on which astrological effects were assigned to the planets. Since Mercury and Venus always remained close to the Sun, they were considered auspicious. Mars, with its red colour reminding one of blood, was feared. The ancient people could not have possibly known that Jupiter was the biggest heliocentric planet. Jupiter's importance probably came from the circumstance that its orbital period was about 12 times that of the Sun, so that Earth's one year became Jupiter's one month. Saturn was called śanicara, or slow-moving. Since it was the farthest planet known beyond which lay the unknown dark world of the stars, it was assigned many menacing attributes. Since comets appeared in the sky unannounced, they were viewed with foreboding.

Zodiacal signs

Another concept that came to India from west Asia via Greece was that of the zodiacal signs or Rāśis. The Sun's apparent path around the Earth defines the ecliptic. All planetary orbits remain close to the ecliptic within 9° north or south of it. While this would have been noticed by various ancient cultures, it is on record that the Babylonians divided this belt into 12 equal parts and gave them rather peculiar names like ram, bull, scorpion, etc. The Babylonian concept was adopted by the Greeks who literally translated the Babylonian sign-names. The name zodiac is credited to the astronomer Cleostratos (*c.* 530 BC). The zodiacal signs came to India in the post-Alexandrian period. The Sanskrit terms are adapted from the Greek, except for some changes, like bow replacing the archer, and crocodile the scorpion.

The remains of the Graeco-Mesopotamian astronomy were preserved in two Sanskrit texts. In AD 149/150, in the reign of Rudradaman-I, probably at Ujjain, one Yavaneśvara translated a long Greek astrological text into Sanskrit prose. In AD 269/270, a large part of this text was versified by Sphujidhvaja in a text entitled *Yavana-jātaka*, which is extant. The term Yavana, literally corresponding to Ionian, was used to denote the Greek. Later, the meaning was extended to mean foreign or the foreigner in general. Greek influence on Siddhāntic astronomy was underscored in terms of Greek origin like hora (time).

IV. SIDDHĀNTIC ASTRONOMY

Before we discuss Siddhāntic astronomy in any detail, it is important to understand the nature of the source material available. The Indian astronomical tradition, like the intellectual tradition in general, was entirely oral. Astronomical texts were composed in terse verse, often in metrical form. One objective of versification was to facilitate memorization; another probably was the desire to follow the format of the *Ṛgveda*, by then considered a revealed text. (There was no difficulty in memorizing Upaniṣads which were in prose form.) Because of the poetic restrictions, different conventions were used to render numbers into syllables. More often, certain important parts of mathematical formulae had to be omitted, and exact terms jettisoned in favour of terms which, though uncommon or vague, met the metrical requirements. The metrical composition, however, had one advantage as far as the authors were concerned: the metre was the author's signature, so that when the later astronomers cited an earlier work, the credit would immediately be given to the original author.

Source Materials

To facilitate teaching, commentaries were composed on famous texts. These commentaries did not aim at explaining the derivation of the rules. They often concerned themselves with expressing the rules in clearer language and in illustrating them with examples. The commentaries served a very useful historical purpose: they told us the status of the original texts at the time a particular commentary was prepared.

The oral tradition was not conducive to tracing the evolutionary history of a subject. This was so, because the oral tradition tended to preserve the end product only while obliterating the intermediary stages. In other words, the drafts and earlier editions of a work were generally not available. As long as an astronomical text was in use, it was memorized. But once it was superseded, its fate became uncertain. If it was still memorized, there was understandable lack of care and accuracy. Very often, the text was forgotten except for fragments incorporated into or cited in other texts.

Very little information is generally available about the astronomers themselves, who were perhaps more keen to record their Gotra (lineage) rather than their place of birth. There were only stray references to the year of birth or the composition of the text. Some works in passing gave the year of death of the cited authors. In many cases, an astronomer could only be assigned approximate relative chronology on the basis of cross-references in dateable texts.

Another source on the Siddhāntic period is the corpus of Persian/Arabic translation of the Sanskrit texts. In addition, Al-Beruni provided valuable information on astronomy as on everything else.

A Siddhānta was comprehensive treatise that calculated mean positions of planets from the beginning of a Kalpa or the current Kaliyuga. If Siddhāntas were the text books, Kāraṇas were the 'made-easy guides'. A Kāraṇa pre-calculated the mean position for an epoch close to the time of composition, and the positions for later times were calculated from there. Koṣthakas or Sāriṇīs were sets or astronomical tables for determining planetary positions or solving other problems in astronomy.

The early Siddhāntic period is rather shadowy. No contemporaneous texts are extant nor are its astronomers identifiable. Whatever we known about this period is from later texts, which call the early texts a-pauruṣeyas, 'non-human' or divine. It is therefore necessary to acquaint ourselves with the historical-period texts and authors before we can learn about the a-pauruṣeya period.

Historical Siddhāntas

The historical era began with Āryabhaṭṭa (b. AD 476) whose AD 499 text *Āryabhaṭīya* (meaning Āryabhaṭṭa's work was the first astronomical work that was attributed to a single author and accurately dated. *Āryabhaṭīya* exercised profound influence on later developments. For more than a thousand years, it was commented upon, followed, adapted, or criticized, but never ignored.

Not much is known about Āryabhaṭṭa himself. His book tells us his year of birth and that he worked at Kusumapura (in Magadha), identified with Patliputra or modern Patna. A commentary written 100 years later (by. Bhāskara-I) implied that Āryabhaṭṭa was from Asmaka, which unfortunately cannot be geographically pin-pointed. Pāṇini recognized Asmaka as marking the boundary of the country as known to him. Asmaka was called Assaka in Pālī texts which placed its capital Pratisthana (modern Paithan) on river Godāvarī. Varāhamihira in his *Bṛhat-saṁhitā* placed Asmaka in the north-west region of India. According to H. Kern, it was the Assaknoi of the Greeks in the Swat valley. However, the Greek word might be a derivative of Asva (house) rather than Asmaka. The lexicographer Vaman Shivram Apte was certainly wrong in placing Asmaka in Kerala. Interestingly, there is a legend in

Kerala that Āryabhaṭṭa and his son Devarāja were excommunicated from their caste (in Kerala) for going to sea to observe an eclipse. The legend seems to translate Āryabhaṭṭa's intellectual influence on Kerala into physical presence.

A comment on Āryabhaṭṭa's name may not be out of place here. Sanskrit distinguishes between two words Bhaṭṭa and Bhaṭa. While Bhaṭṭa means a learned Brahmin, the dictionary meaning of Bhaṭa is a soldier, a mercenary, a barbarian, or an outcast.

Illustrious names in Siddhāntic astronomy following Āryabhaṭṭa were his direct pupil Latadeva (AD 505): Varāhamihira (d. AD 587), a compiler rather than researcher, and an expert on omens; Bhāskara-I (AD 629), Āryabhaṭṭa's commentator and an able mathematician; Āryabhaṭṭa's bete noire Brahmagupta (b. AD 598); Lalla (AD 638 or 768); Manjula or Munjala (AD 932); Āryabhaṭṭa-II (*c.* AD 953); Śrīpatī (AD 1039); and Bhāskara-II (b. 1114), author of the celebrated mathematical work *Līlāvatī.* (A date not preceded by b. or d. refers to the year of composition of a work or the epoch used in the calculations.)

A powerful school of astronomy, mostly based on Āryabhaṭṭa's system, flourished in Kerala from thirteenth century right into the nineteenth. It included such illustrious names as Parameśvara (who in AD 1413 introduced the Dṛggaṇita system) and Acyuta Pisarati (d.1621). Many astronomers composed commentaries on earlier authoritative works. Among the commentators were such well-known names as Pṛthudaka (AD 864) in Kannauj and Bhaṭṭotpala (AD 966) in Kashmir. There were also a number of astronomers whose own works were not extant but were cited by others.

Siddhāntic Theory

The basic observational input into the Siddhāntic theory was the orbital periods of the geocentric planets, which would have been obtained by actual observation. However, instead of saying that Saturn's period was 29.47 years, a Siddhāntic astronomer would, for instance, say that Saturn made 146,564 revolutions in a Mahāyuga. Since the figures were very large, astronomers could play around with numbers in the unit's and ten's places for mathematical tractability without seriously affecting their accuracy.

At a chosen epoch, all planets were supposed to be aligned. After the lapse of long period of time (like a Mahāyuga), during which the planets made an integral number of revolutions, the planets returned to the original alignment. An important new concept was introduced by Āryabhaṭṭa by assigning a beginning to the current Kaliyuga, which, it might be recalled, was the fourth and final part of the current Mahāyuga. According to *Āryabhaṭīya*, the Kaliyuga began from sunrise on Friday, 18 February 3102 BC (Julian) at Lanka, hypothetically placed on the intersection of the equator with the meridian of Ujjain. This system was known as the Āryapakṣa (Arya school).

In a text no longer extant, Āryabhaṭṭa also propounded the Ardha-rātrika (midnight) system in which the beginning of Kaliyuga was placed six hours earlier, at the midnight of 17/18 February 3102 BC. The choice of the date was not fortuitous. On the basis of the observational data available to Āryabhaṭṭa, 21 March AD 499, 12 noon at Ujjain would exactly correspond to the beginning of the year 3600 of the Kaliyuga. To achieve this in both Āryapakṣa and Ardha-ratrika-paksa, Āryabhaṭṭa arbitrarily shortened the length of the year by a suitable amount in the Ardha-rātrika system. Modern simulations have shown that the planets were not in conjunction in 3102 BC. In any case, because of the motion of the planets, they could not have been in conjunction both at midnight and sunrise.

The date 3102 BC has earned a non-astronomical connotation because of Āryabhaṭṭa's peculiar way of describing it. Instead of using the expression before Kaliyuga, he said Bhārtāt-pūrvam (before the Bhārata or battle), alluding to the Purāṇic belief that the (historical) Kaliyuga began at the time of the *Mahābhārata* battle. This confusion between the astronomical and Purāṇic Kaliyugas has led to the Bhārata battles being wrongly placed at 3102 BC. It is important to recall that this date was not known to the Purāṇas and did not figure anywhere before the *Āryabhaṭīya*.

We can now summarize the various schools, or Pakṣas, of the classical Siddhāntic astronomy: Brahma, Arya, Ardha-rātrika, and Saura. They all retained the traditional duration of a Mahāyuga, but differed from each other in their choice of other units of time. We have already encountered the Brahma-pakṣa, in which, we might recall, a Kalpa was made of 1000 Mahāyugas, each of which was divided into four unequal parts, named Kṛta, Tretā, Dvāpara, and Kaliyuga, with duration in the ratio 4:3:2:1. In this Pakṣa, planetary revolutions were reckoned from the beginning of the Kalpa. The Saura-pakṣa was the same as the Brahma, except that, the for some reason, there was an initial period of non-motion at the beginning of the Kalpa equal to 17,064,000 years.

Āryabhaṭṭa's Āryapakṣa and Ardha-rātrika-pakṣa differed from the Brahma-pakṣa in two important aspects: Āryabhaṭṭa set a Kalpa equal to 1008 Mahāyugas (or 72 Manvantaras). Since 1008 was divisible by 7, this ensured that each Kalpa would begin on the same week day. Secondly, Āryabhaṭṭa divided his Mahāyuga into four equal Yugas, so that each one of them contained an integral number of revolutions. Tables 1 and 2 list important Siddhāntic and Kāraṇa works, respectively.

Table 1. *Important Siddhāntas*

Author[1] *(Year)*[2]	*Place*	*Work (Year)*[3]	*Remarks*
Āryabhaṭṭa-I (b.476)	Patna (Bihar)	Āryabhaṭṭa-siddhānta Āryabhaṭīya (499)	4 5
Latadeva	. . .	Reductions of Saura, Romaka, and Paulisasiddhāntas	6
Brahmagupta (b.598)	Bhillamala (Rajasthan)	Brahma-sphuṭa-siddhānta (628)	7
Bhāskara-I	Valabhi (Gujarat)	Mahā-bhāskarīya (629) Laghu-bhāskarīya	8
Lalla	Dasapura (Malwa)	Śiṣya-dhi-vrddhida (748)	9
Anon.	. . .	Sūrya-siddhānta (*c.* 800)	10
Vateśvara (b.880)	Vatanagara (north Gujarat)	Vateśvara-siddhānta (904)	11
Āryabhaṭṭa-II	..	Mahā-siddhānta (*c.* 953)	12
Śrīpatī	Rohiṇikhaṇḍa (south of Ujjain)	Siddhānta-śekhara (*c.* 1050)	13
Bhāskara-II (b.1114)	Vijjalavida	Siddhānta-śiromaṇi (1150)	14
Parameśvara (d.1455)	Kerala	Dṛg-gaṇita (1430)	15

Author[1] *(Year)*[2]	*Place*	*Work (Year)*[3]	*Remarks*
Nīlakaṇṭha Somayaji (b. 1444)	Kundapura (Kerala)	Tantra-saṁgraha (1501)	16
Jñānarāja	Parthapura (Godāvarī)	Siddhānta-sundara (1503)	17
Acyuta Pisarati	Kerala	Sphuṭa-nirṇaya (m̄1593)	18
Nityānanda	Kurukshetra	Sarva-siddhānta-raja (1639)	19
Munīśvara (b. 1603)	Varanasi	Siddhānta-sarvabhauma (1646)	20
Kamalākara	Varanasi	Siddhānta-tattva-viveka(1658)	20
Candraśekhar Simha(1835-1904)	Khandapra (Orissa)	Siddhānta-darpaṇa (1894)	21

NOTES:

1. Many authors are listed in Table 2 as well; many of them composed other works, including commentaries.
2. Year of birth/death wherever known.
3. Year of composition of the work.
4. Introduces the Ardha-rātrika-pakṣa.
5. Introduces the Āryapakṣa.
6. The 'original' Saurasiddhānta recast in the Ardha-rātrika-pakṣa.
7. Follows the Brahma-pakṣa.
8. Follows the Āryapakṣa.
9. Introduces the modified Āryapakṣa to accommodate Brahmagupta's ideological criticism.
10. Introduces Saura-pakṣa; recast a number of times until 1603.
11. Last major representative of Āryapakṣa in north and west India, which came to follow Brahma-pakṣa pushing Āryapakṣa to south India.
12. Follows a variant of Brahma-pakṣa.
13. Follows Brahma-pakṣa.
14. The foremost text of Brahma-pakṣa after *Brahma-sphuṭa-siddhānta.*
15. Introduces the dṛg-system, based on the Saura-pakṣa.
16. Introduces new numbers of rotations of planets in Āryapakṣa's Yuga system; elsewhere he refers to observation of eclipses in 1467 and 1501.
17. Includes a Kāraṇa. The family produced astronomers for many generations.
18. Introduced the correction called 'reduction to the eclipse', which was independently introduced by Tycho Brahe in Europe at about the same time.
19. Not consistent with known Siddhāntas; claims to be based on own observations.
20. Based on Saura-pakṣa.
21. Modelled after Bhāskara-II's work (note 14).

Table 2. *Important Kāraṇas*

Author[1] *(Year)*[2]	*Place*	*Work (Epoch)*[3]	*Remarks*
Varāhamihira (d.587)	Ujjain	Pañca-siddhānta (505)	4
Brahmagupta (b. 598)	Bhillamalla (Rajasthan)	Khaṇḍa-khādyaka (665)	5
Haridatta	Kerala	Graha-cara-nibandhana (683)	6
Vateśvara (b. 880)	Anandapura	Kāraṇa-sāra (890)	7
Manjula (or Munjala)	Prakashapattam	Bṛhad-mānasa (932) Laghu-mānasa	8
Vijayananda	Varanasi	Kirana-tilak (966)	9
Śrīpatī	. . .	Dhi-kotida-kāraṇa (1039)	10
Bhojarāja	Dhara	Raja-mṛganka (1042)	11
Brahmadeva	Mathura or Madurai	Kāraṇa-prakāśa (1092)	12
Satanvanda	Puri (Orissa)	Bhasvati (1099)	12
Asadhara	Gujarat	Graha-jnana (1132)	14
Bhāskara-II (b. 1114)	Vijjalaerda (Bijapur)	Kāraṇa-kutuhala (1183)	14
Vararuci (?)	Kerala	Candra-vakyani (1184)	15
Śrīdhara	. . .	Laghu-khecera-siddhi (1227)	16
Lakṣmīdhara	. . .	Sighra-siddhi (1278)	17
Varilova Koccanna	Telangana	Unnamed Kāraṇa (1297)	18
Cakreśvara and Mahādeva	Rasina (Godāvarī)	Mahādevi-sśriṇī or Graha-siddhi (1316)	19
Mahādeva	Tryambak (Godāvarī)	Kāmadhenu-Kāraṇa (1367)	20
Damodara	..	Bhaṭa-tulya (1417)	21
Keśava	Nandgaon (Maharashtra)	Graha-kautuka (1496)	22

Author[1] *(Year)*[2]	*Place*	*Work (Epoch)*[3]	*Remarks*
Jñānarāja	..	Siddhānta-sundara (1503)	23
Gaṇeśa Daivajñā	Nandgaon (Maharashtra)	Graha-laghava or Siddhānta-rahasya (1520)	24
Citrabhānu	Kerala	Kāraṇāmṛta (1530)	25
Raghunātha	. . .	Maṇi-pradīpa (1565)	26
Rāma-candra	. . .	Rāma-vinoda (1590)	27
Acyuta Pisarati (d. 1621)	Kerala	Kāraṇottama (*c.* 1593)	28
Bhāva-sadā-śiva	. . .	Laghu-kāraṇa (1598)	29
Viṣṇu	Gologram (Godāvarī)	Sūrya-pakṣa-Karana or	30
Kṛṣṇa	Tataka (Konkan)	Kāraṇa-kaustubha (1653)	31
Jātadhara	Sirhind (Punjab)	Phattesaha-prakāśa (1704)	32
Somayajin Putumana	Kerala	Kāraṇa-paddhati (1733)	33
Nandarama Misa	Kamya-vana (Rajasthan)	Grahaṇa-paddhati (1765)	34
Śaṅkara	. . .	Kāraṇa-vaiṣṇava (1766)	35
Manirama	Gujarat	Graha-ganita-Cintāmaṇi (1774)	36
Bhula	Dadhici (Narmadā)	Brahma-siddhānta-sāra (1781)	37
Śaṅkara Varma	Kataattanat (north Malabar)	Śaḍa-ratna-mālā (1823)	
Jyotirāja	Nepal	Jyotirāja-Kāraṇa (1832)	

NOTES:

1. Asterisk after the name denotes appearance in Table 1 also
2. The year of birth/death wherever known.
3. The epoch used in the calculations, believed to be near the year of composition.
4. Incorporates summaries of Latadeva's reductions.
5. Follows Ardha-rātrika-pakṣa.
6. Introduces the Parahita system, based on Āryapakṣa.
7. Known only from Al-Beruni's reference.
8. Bṛhad-mānasa no longer extant; Laghu-mānasa, based on Ārya- and Ardha-rātrika-pakṣas, was th subject of a number of later commentaries.

9. The earliest known Kāraṇa belonging to the Saura-pakṣa; known not from Sanskrit text but from an Arabic translation made for Al-Beruni about 1030.
10. Belongs to Brahma-pakṣa; describes computation of solar and lunar eclipses.
11. Attributed to Raja Bhoja; belongs to Brahma-pakṣa.
12. Belongs to Āryapakṣa as modified by Lalla.
13. Follows Varāhamihira's summary of Sūrya-siddhānta.
14. Belongs to Brahma-pakṣa.
15. The earliest epoch of the vākya system of calculations, derived from the Parahita system (note 6); the Kerala tradition associates the vākya system with Vararuci, about whom nothing is known.
16. Belongs to Brahma-pakṣa.
17. Sets of tables for both Brahma- and Ārya-pakṣas.
18. Known from incorporation in John Warren's Kalā-saṁkalita (1825), published in Madras.
19. Begun by Cakreśvara and completed by Mahādeva; follows Raja-mṛganka (note 11).
20. Follows Brahma- and Ārya-pakṣas.
21. Meaning Arya (bhaṭṭa)'s equal, the work follows Āryapakṣa as modified by Lalla.
22. Father of Gaṇeśa Daivajñā (note 23)
23. Patterned after Sūrya-siddhānta; also included in Table 1.
24. Introduces Gaṇeśa-pakṣa.
25. A pupil of Nīlakanṭha (Table 1).
26. Follows Saura-pakṣa.
27. Belongs to Saura-pakṣa; used at Akbar's court.
28. Wrote a number of books including a treatise on eclipses, entitled Uparāga-kriyākrama (1593).
29. Follows Brahma-pakṣa.
30. Follows Sūrya-pakṣa.
31. Follows Gaṇeśa-pakṣa; composed under Śivāji's patronage.
32. Named after the king of Badri Kedar, in Kashmir.
33. Last major work in Kerala astronomy.
34. Author was probably the teacher of Śaṅkara (note 35).
35. Last full-scale work on Brahma-pakṣa.
36. Claims to be based on actual observations.
37. Follows Brahma-pakṣa.

Pañca-Siddhāntika

We now return to examine the pre-Āryabhaṭīan, Apauruṣeya period. Our chief source of information is Varāhamihira's compendium, aptly called *Pañca-Siddhāntika*, because it described the five (pañca) ancient Siddhāntas. Arranged in order of increasing accuracy they were the Paitāmaha, Vaśiṣtha, Romaka (of the Romans), Paulisa (by Paulus), and Sūrya.

The Paitāmaha was dismissed by Varāhamihira in five couplets. Its epoch was determined to be 11 January AD 80. Like the *Vedāṅga Jyotiṣa*, it dealt only with the Sun and the Moon, and used a five-year Yuga. Its year length, however, was more accurate than the Vedāṅga's. Brahmagupta cited the Paitāmaha on Mars and other planets, which did not figure in Varāhamihira's summary. This meant that there must have been another version. Indeed, a Paitāmaha-siddhānta of the early fifth century AD was preserved as a part of *Viṣṇu-dharmottara-purāṇa*. The Siddhānta was cast in the form of a lecture by God Brahma to Bhṛgu. One suspects that this Paitāmaha was a more competent work than what we now possess of it'. It seemed to be the source of Brahma-pakṣa used by Brahmagupta in his *Brahma-sphuṭa-siddhānta*. It was probably identical to the Svayaṁbhūva-siddhānta, which, Bhāskara-I told us, was held in high esteem by the learned people of Kusumapura, including Āryabhaṭṭa.

The *Pañca-Siddhāntika* devoted 13 verses to the *Vaśiṣtha-siddhāntas* whose epoch was 3 December AD 499. Varāhamihira, who must have reworked the elements, called it very inaccurate. There must have been an earlier version also, because a *Vaśiṣtha-siddhānta* was cited by Sphuji-dhvaja in AD 269/270. From the post-Varāhamihira period, we had a *Vaśiṣtha-siddhānta* by Viṣṇucandra (before Brahmagupta's time) and a later *Vṛddha-Vaśiṣtha-siddhānta*.

The Romaka and the Paulisa-siddhāntas included in the *Pañca Siddhāntika* were the summaries of versions prepared by Latadeva, for the epoch of 21 March AD 505, sunset at Yavanapura (Alexandria). The Romaka did not use a Mahāyuga. Rather, it used a 2850-year Yuga, apparently obtained by multiplying together the 19-year so-called Metonic cycle, 5-year Vedic Yuga, and 30 Tithīs. The length of the year was identical with the value (365.2467 days) used by Hipparchus (*c.* 150 BC). Of all the Siddhāntas, the Romaka alone gave the length of a year which was unmistakably tropical, and introduced the concept of the precession of equinoxes.

The Romaka-siddhānta represented a school distinct from the mainstream. One of its later propounders was Srisena, who flourished between Āryabhaṭṭa and Brahmagupta. Srisena was roundly criticized by Brahmagupta for having made a Kantha, or patchwork, by borrowing elements from different Siddhāntas. Viṣṇucandra was similarly criticized for compiling the *Vaśiṣtha-siddhānta* by borrowing the same elements.

A large part of *Pañca-Siddhāntika* was devoted to the Paulisa, which used a sidereal year. It continued to be current up to the time of Bhaṭṭotpala (AD 966) who quoted from it. No text of this Siddhānta is now extant.

Of the five Siddhāntas mentioned by Varāhamihira, the *Sūrya-siddhānta* alone has survived. It was supposed to have been described by the Sun-god himself to Asura Māyā, the architect of the gods, who in turn revealed it to the Indian Ṛṣis. The legend is ironical, because there is concrete evidence of the continuous revision of the Sūrya-siddhānta in the light of contemporaneous developments. While in astronomical circles, texts were known by their author's name, the contents were presented as a divine package to the common man, no doubt to increase their astrological market value.

It seems there was an original *Sūrya-siddhānta* about which nothing is known. It was recast into the Ardha-rātrika system (epoch midnight 20/21 March AD 505) by Latadeva. This version was incorporated into *Pañca-Siddhāntika.* Then again, elements were borrowed from Brahmagupta's *Siddhānta* (AD 628). The current Sūrya-siddhānta is believed to have been composed in the late eighth or early ninth century. The text as we know it now was fixed in AD 1603 by Ranganatha in Benaras: there have been no changes after that .

The siddhāntic astronomical tradition was alive till as late as 1825, when John Warren found a 'Kalendar maker residing in Pondicherry' who showed him how to compute a lunar eclipse by means of shells, placed on the ground, and from tables memorized 'by means of certain artificial words and syllablea'. The predictions for the lunar eclipse of 31 May/1 June 1825 contained an error of +4 minutes for the beginning, –23 minutes for the middle and –52 minutes for the end. The Siddhāntic calculations were probably accurate anywhere till they were superseded by the post-Keplerian almanacs.

Earth's Rotation

A notable feature of Āryabhaṭṭa's work was his reference to the Earth's spin about its axis, which was mentioned at three places in *Āryabhaṭīya.* Stanza 3 of the Gītikā section (Gītikā: 3) referred to Earth's rotation in a Yuga; Gītikā: 6 stated that earth rotated by one minute of arc in four seconds of time; and Gola: 9 physically explained that sitting on the Earth, we perceived the asterisms as moving backwards.

Pṛthudaka (AD 860) and Makkibhaṭṭa (AD 1377) subscribed to this view: and even a Purāṇa, the *Skanda-purāṇa* (1.1.31.71), described the Earth as revolving like a Bhramarikā (spinning top). The concept of Earth's spin, however, ran counter to the received wisdom on the subject. Varāhamihira and Brahmagupta even listed physical arguments as to why the Earth could not be in motion. Āryabhaṭṭa's belief in Earth's rotation was generally a source of embarrassment to his followers down the ages, who sought a way out by attributing Gītikā:

1 and Gola: 9 to Mithyā-jñāna (false knowledge) on the part of Āryabhaṭṭa. Since this charge could not be held against the explicit statement in Gītikā: 6, here the original term Bhuh was changed to Bhama. Ironically, we learn of the correct form of this stanza from the citation by Āryabhaṭṭa's critics.

It is, however, intriguing that Āryabhaṭṭa was not entirely self-consistent: a static Earth was implied in Gola: 9, which stated that the asterisms, together with the planets, were driven by the protector winds. No satisfactory explanation seemed to available for Āryabhaṭṭa's volte-face.

The episode brought into focus the intellectual limitations of the oral Śloka-type scientific texts. If Āryabhaṭṭa's arguments in support of the hypothesis of Earth's spin had been explicitly recorded, they would have survived the intellectual fashion of the day, and gone into a knowledge-bank from where they might have been later resurrected by some body cast in Āryabhaṭṭa's bold mould .

It should however be kept in mind that Āryabhaṭṭa's belief in the Earth's rotation was at the level of a hypothesis, acceptance or negation of which had no bearing on the planetary calculations. After all, Āryabhaṭṭa like everybody else could believe in the geocentric Universe and carry out his work without experiencing any disadvantage.

Rāhu and Ketu

The Vedic mythology attributed the eclipses to a demon Rāhu, who was explicitly named in *Atharvaveda*. The correct mathematical theory of eclipses was first given by Āryabhaṭṭa in the Indian context. He pointed out that for an eclipse to occur, the moon should be at one of its nodes, that is, at one of the two points where the lunar orbit intersects the ecliptic. Subsequently, the term Rāhu was borrowed from the Vedic texts and applied to the lunar node, especially the ascending node (when the moon crossed the ecliptic moving northwards). At the same time, the mythology was modified to keep pace with the scientific developments. The old single demon Rāhu was cut into two, the head Rāhu and the torso Ketu to correspond to the two nodes. Ketu was also of Vedic vintage, but not connected with the eclipse. *Atharvaveda* referred to Dhūma-Ketu, 'smoke-bannered', as an epithet of mṛtyu, 'death'. It was surmised that Dhūma-Ketu, referred to the smoke rising from a funeral pyre.

Rāhu and Ketu, the two nodes, are 180° apart. The determination of one fixes the other. Still they are referred to as two 'planets' in the astrological texts. Varāhamihira in his *Bṛhat-saṁhitā* names the two.

The concept of Rāhu and Ketu travelled outside India also. In the Burmese tradition, Yahu (no doubt the same as Rāhu) was regarded as a Nat (or spirit) which was responsible for partial eclipses. In the Shwe Dagon Pagoda in Rangoon, a person's birthday is represented by eight 'planetary posts', including Yahu.

Far more significant is the reference in the Chinese sources. Rāhu and Ketu, the two 'invisible luminaries', were introduced into China along with Buddhist scriptures in the Tang dynasty (AD 806). A work called *Qi Yao Rang Zai Jue* (or 'Formulae for warding of calamities according to the seven luminaries'), was compiled by the Indian Buddhist monk, Jin Ju Zha. This work gave detailed ephemerides of Rāhu and Ketu, which were incorporated into Tang calenderical calculations. Interestingly, while Rāhu stood for the ascending node, Ketu denoted the lunar apogee, an identification not known in India.

Throughout the Siddhāntic period, instruments and observations played second fiddle to computations. Observational results were not explicitly recorded, and descriptions of astronomical instruments were condensed into a single chapter, Yantra-adhyāya. Although Bhāskara-II was credited with devising a rather versatile instrument, Phalaka-yantra, there was no gainsaying the fact that observational astronomy came into its own only in the medieval times, again thanks to India's interaction with central and west Asia.

V. ZIJ ASTRONOMY

The post-Siddhāntic world astronomy had been referred to by a number of names, most of which were misnomers. 'Arab astronomy' was not a correct expression because most of the astronomers in this period were non-Arabs. (According to Ibn Khaldun (1332-1406): 'It is a remarkable fact that, with few exceptions, most Muslim scholars both in the religious and in the intellectual sciences have been non-Arabs.') The term 'Islamic astronomy' was politically incorrect, and in the Indian context factually wrong as well because, contrary to the popular belief, this astronomy was Sanskritized. The more recent term like 'central and west Asian astronomy' appears laboured, and is spatially restrictive. The most appropriate term therefore, was 'Zij astronomy', because the main occupation of astronomers in this phase was the preparation of Zijes—that is, mathematical tables.

Types of Zijes

There were three types of Zijes: (i) Zij-e-Rashadi (direct tables) based on actual observations; (ii) Zij-e-Hisabi (calculated tables) obtained by correcting observational tables for errors, precession, etc.; and (iii) Zij-e-Tas'hil (simplified tables) which were the simplified versions of other tables—like the one which could deal with the Moon alone.

The Zij period began in Baghdad under the auspices of the Abbasid Caliphate. The sovereign rulers of the Abbasid dynasty, which came to power in AD 750, were all members of prophet Muhammad's family, being descendants of his uncle Al-Abbas. To place the astronomical developments of the period in the political context, we may note the sequence of the early Abbasid Caliphs: Al-Saffah (750-54), Al-Mansur (754-74), Al-Mahdi (775-85), Al-Hadi (785-86), Harun Al-Rashid (786-809), and Al-Mamun (813-33).

The starting point of the Zij astronomy was the translation of first the Sanskrit and then the Greek texts into Arabic. The Arabic bibliographical tradition recorded the name of an Indian astronomer Kankah-al-Hindi (*c.* 775-820), who was not know to Indian sources at all. He was probably the author of *Kitab Kankah Al-Hindi* (preserved as a manuscript at Ankara), giving an astrological history of the Abbasids up to part of the reign of Al-Mamun. Kankah was perhaps an astrologer who migrated from India to Baghdad. A number of legends have grown around Kankah, who is best seen as a personification of the transmission of scientific knowledge from India to west Asia.

The first regular astronomer to be known in Arabic was Brahmagupta whose *Brahmasphuṭa-siddhānta* was the basis of a work entitled *Mahā-siddhānta* composed in the late seventh or early eighth century. This work was in turn the basis of *Zij Al-Sindhind Al-Kabir* composed by Al-Fazari during the reign of Al-Mansur. The *Āryabhaṭīya* was translated into Arabic as *Zij Al-Arbhar* in about AD 800.

The next step was to imbibe Greek scholarship. Harun Al-Rashid ordered the Greek manuscripts to be assembled. His successor, Al-Mamun, while signing a peace treaty with the Byzantine emperor stipulated the handing over of numerous Greek manuscripts. These manuscripts included Ptolemy's work, known since antiquity as *Megiste*, or 'very great'. In translation, it was given the hybrid name *Almagest* by combining 'megiste' with the Arabic article 'al'. (Many English scientific terms beginning with al, like Aldebaran, Algebra and Almucanter are of Arabic origin.)

Al-Mamun established an intellectual academy Bayt Al-Hikma ('the house of wisdom'), which attracted scholars from all over, especially from Greece and central Asia. He set up observatories at Baghdad and Damascus. The first astronomical tables in Arabic were prepared by translation from Sanskrit by Muhammad ibn-Musa Al-Khwarizmi (780-850). As expected, they gave all numerical data for the meridian of Ujjain. Devoid of any theory, they were obviously meant for calendrical and astrological purposes. A later version of these tables was translated into Latin in AD 1126 by Athelhard of Bath, who specially went to Spain to learn Arabic. Al-Khwarizmi's tables constituted a landmark in the world history of astronomy and mathematics; they represented the westward migration of the Indian numerical system, including zero. Interestingly, while these numerical were called Hind-se (from India) in Arabic, they were termed Arabic in Europe, acknowledging the supplier rather than the originator. (The English term Algorithm was derived from Al-Khwarizmi).

One of the greatest Zij astronomers was Muhammad ibn-Jabir ibn-Sina Abu-Abdallah Al-Battani (d. 928), known to Europe as Albategnius. His own observations extending from 877 to 918 figure in his *Az-Zij-as-Sabi.* He was the first to introduce into his tables the Siddhāntic half-chords (sines) for half-angles. The etymology of the term sine is instructive. The Sanskrit term Jaya for the half-chord was rendered into Arabic as Jayb. When the Arabic texts were translated into Latin, the term Jayb, also meaning bosom in Arabic, was literally translated as sinus, meaning curve or fold of toga.

Umar Al-Khayyam, now better known as a poet than astronomer, was the director of an observatory built by Malik Shah of Saljuki dynasty. His work came to be known as *Zij-e Khayyam.* The Mongol ruler Halaqu Khan, a grandson of Changez Khan set up an observatory at Maragha (near Tabriz in Iran) in 1258 under the direction of Nasir al-din Al-Tusi (1201-74) from Khurasan. A library of four lakh manuscripts was assembled and many instruments were constructed, often to a new design. Among these was great quadrant of 10 feet radius constructed by Al-Urdi. Assiduous observations lasting a dozen years resulted in the influential *Zij-e-llkhani.* It consisted of four maqales (chapters) dealing with different eras; stellar longitudes and astrological predictions. Each maqala was supplemented with a number of tables.

Observational Zij

This arrangement was followed by most subsequent Zijes. A hundred years later, Zij-e Ilkhani was amended by Ghyathuddin Jamshid bin Masud Al-Kashi (d.1429) under the (abbreviated) title *Zij-e Khaqani.* This Zij was completed at Samarqand where Al-Kashi was invited to assist Ulugh Beg (1394-1449), the most outstanding observational astronomer of the medieval times. Ulugh Beg ruled over a stretch of land around Samarqand (now in Uzbekistan). At Samarqand, Ulugh Beg built a madrasah (university) in 1420 and an observatory in 1424. At the observatory, Al-Kashi was followed by Salabuddin Musa, better known as Qadi Zadah Al-Rumi (*c.*1364-1436), who in turn was succeeded by Alauddin Ali bin-Muhammad Al-Qushji (d.1474/75). On Ulugh Beg's death, Al-Qushji moved over to the Sultan of Iran and served as his envoy to Turkey. During 1451-75, he wrote, at Tabriz in Iran, a popular treatise on elementary astronomy and astrology, called *Risalah fil-l-Hai'at.*

Ulugh Beg's observational Zij was finally completed in 1436. It goes by different names. It would be interesting to know if the different names are merely synonyms or refer to the various evolutionary stages of the final text. Ulugh Beg's work became as famous as the *Almagest.* His star catalogue was the first independent catalogue after Hipparchus (second century BC). It formed the basis of most subsequent catalogues, and was used even by Johan Flamstead (1646-1719), the first Astronomer Royal at Greenwich Observatory. Ulugh Beg's work held sway for close to three centuries, when it was supplanted by telescopic data.

In the Indian context, Ulugh Beg was well known for another reason. He was a collateral paternal ancestor of the Mughal emperors, the common link being Timur. (The designation Mughal, Persian for Mongol, referred to Babur's maternal ancestry.) Babur, the founder of the Mughal dynasty, was the fifth descendent of Timur, whereas Ulugh Beg was Timur's grandson through another son. Ulugh Beg's work was also called *Zij-e-Gurgani* after Gurgan, a title used by Timur. (Gurgan literally meant a prince from both father's and mother's side). Babur in his autobiography proudly noted (in the chapter on the year AH 903) that the

Gurgani Zij was then used throughout the world. He also recorded a couplet which was memonic to calculate the date of Ulugh Beg's assassination (27 October 1449).

Development of Zij Astronomy in India

India's nominal introduction to Zij astronomy came about at the hands of Al-Beruni (973-1048) who himself wrote *Zij-e Masudi*, also called *Qanun-a1-Masudi*. In the thirteenth century, in the wake of the Mongol conquest of central Asia and Iran, many men of learning including astronomers moved over to politically and intellectually congenial India. India's first Zij was prepared by one such asylum-seeker, Mahmud bin Umar. The work was called *Zij-e-Nasiri* after the Sultan of Delhi Nasir Al-Din Abul-Muza Mahmud bin Shams Al-Din Iltutmish (reign 1246-65). Zij astronomy took root in India under the patronage of Feroze Shah Tughlaq who ruled from Delhi from 1351 to 1388. It was during this period that the versatile portable astronomical instrument Ustarlab or the astrolabe was introduced to India. Feroze Shah was himself known to be an expert at making astrolabes. According to his contemporaneous biographer, he always kept an astrolabe by his side, and painted it on his flag. He was said to have himself made an astrolabe, after an Alexandrian specimen, that could be used in both northern and southern hemispheres. (Such an astrolabe must have been built as a designing challenge, rather than for actual use by a peripatetic astronomer). This astrolabe was placed on the highest minar of his capital Ferozabad (in Delhi). In years to come, many astrolabes were constructed, and Arabic and Persian Zijes copied and often commented upon.

In addition, Feroze Shah took steps to Sanskritize instrumentation astronomy. Mahendra Suri, the head astronomer at the royal court, prepared in 1370 a monograph on astrolabe, titled *Yantra-raja*. This was the first Sanskrit work exclusively devoted to instrumentation, and was the subject of many later commentaries. In about 1400, Padmanābha described an astrolabe whose design was different from Suri's and therefore taken from a different source. More importantly, he also described an instrument, dhruva-bhramana-yantra, which measured time by an observation of the star group 'polar fish', that included the bright pair Alpha and Beta Ursae Minous. Table 3 lists Sanskrit texts exclusively devoted to astronomical instrument.

Table 3. *Instrumentation Texts in Sanskrit*

Year	*Author (Place)*	*Work*	*Instrument*
1370	Mahendra Suri (Delhi)	Yantrarāja	Astrolabe
*c.*1400	Padmanābha	Yantra-kiranavali	Astrolabe, Dhruva-bhramana-yantra
1428	Rāmacandra (Sitapur, U.P.)	Yantra-prakasa	Misc.
15th cent.	Hema (Gujarat)	Kasa-yantra	Cylindrical sundial
b.1507	Gaṇeśa Daivajñā	Pratoda-yantra	Cylindrical sundial
		Sudhiranjana-yantra	Graduated strip

Year	*Author (Place)*	*Work*	*Instrument*
c. 1550-1650	Cakradhara (Godavari)	Yantra-cintamani	Quadrant
1572	Bhudhara (Kampilya)	Turiya-yantra-prakāśa	Quadrant
*c.*1580-1640	Jambusara Visrama (Gujarat)	Yantra-siromani (1615)	Misc.
fl. 1720	Dādābhāi Bhaṭṭa	Turiya-yantrotpatti	Based on Cakradhara's work
1688-1743	Jai Singh Sawai (Jaipur)	Yantra-prakara Yantra-raja-racana	Misc. Astrolabe
*c.*1690-1750	Jagannātha (Jaipur)	Samrata-siddhanta (1732)	Tr. of *Almagest* with suppl. on instruments
c. 1700-1760	Lakṣmipati	Dhruva-bhramana-yantra Samrata-yantra	..
c. 1700	Nayansukha	Yantra-raja risala-bisa-baba or Yantra-raja-vicāra-vimsadhyay	Astrolabe (Tr. of MSS by Nasir al Din Al-Tusi 13th cent., Iran)
*c.*1750-1810	Nandarama Misra (Kamyakavana, Rajasthan)	Yantra-sara (1772)	Misc.
c. 1750-1810	Mathuranatha Sukla (Varanasi)	Yantra-raja-ghatana (1782)	Astrolabe
c. 1736-1811	Cintāmaṇi Dikṣita	Golananda (1800)	Misc.

All cultural activities at Delhi, including astronomy, came to a halt as a result of Timur's invasion (1398-99) and had to await establishment of an empire by his descendants.

Babur's son Humayun (reign 1503-56) was said to have been an expert in using 'astrolabes, globes and other instruments of the observatory'. According to his sister, he himself chose the propitious moment for his marriage, using an astrolabe. Under his patronage, the manufacture of astrolabes started at Lahore, with a single family remaining active for generations. The founder of this family was (Ustād) Shaikh Allah-dad Asturlabi Humayuni Lahuri (or 'Shaikh Allah-dad, master maker of Humayun's astrolabes at Lahore'). These astrolabes were quite faithfully modelled after the contemporaneous Persian specimens. It has been pointed out that, for over a century and a half during which these astrolabes were made, their design remained static, implying that they were made more for decoration than for actual use. In any case, some of them were too big for astronomical observations.

Humayun's astronomer Mulla Chand used an astrolabe to determine the time of Akbar's birth. Chand was also Akbar's court astronomer. We know from later references (in *Zij-e Shah Jahani* and *Zij-e Muhammad Shahi*) that Chand prepared a Tas'hil or gloss on Ulugh

Beg's Zij; however, no copy of it is known to exist. According to Abul Fazl, there were 86 different Zijes known in Akbar's time.

Shah Jahan's court astronomer Fariduddin Masud bin Hafiz Ibrahim Munajjim (d. 1627) computed his *Zij-e Shah Jahani* based on Ulugh Beg's observations. He also gave detailed classification of all Zijes compiled till his time. This Zij was translated into Sanskrit by Nityānanda (*c.*1639). Interestingly, Shah Jahan even toyed with the idea of setting up an observatory, and asked Mullah Mahmood Jaunpuri to prepare the plans. The idea, however, was given up because all the funds had to be diverted to building the mausoleum for queen Mumtaj Mahal.

Jai Singh's Observatories

From the eighteenth century, we have Raja Jai Singh Sawai's (1688-1743) treatise on instruments, *Yantra-prakara,* essentially completed before 1724, with some additions made up to 1729. In 1732, his astronomer Jagannātha translated Al-Tusi's Arabic recension of *Almagest* into Sanskrit under the title *Samrata-siddhānta,* adding a supplement to it describing various instruments.

Jai Singh set up a number of (pre-telescopic) masonry-type observatories. The Delhi observatory established during 1721-24 was followed by a bigger one built during 1728-34 at his capital Jaipur. He built smaller ones at Mathura, Ujjain and Varanasi between 1723 and 1734. (All dates are estimates.) The Varanasi observatory was set up on the terrace of Manamandira, a palace built by Jai Singh's ancestor Man Singh (1550-1614); it was likely that he renovated an old observatory. Jai Singh's observatories were modelled after those of the 'martyr-prince' Ulugh Beg. Curiously, though Samarqand observatory was built three centuries prior to the ones at Delhi and Jaipur, Ulugh Beg's instruments were more accurate than Jai Singh's.

Jai Singh's instruments and observations have been extensively dealt with in literature. Let us therefore examine the political and scientific context of his work. Jai Singh was not a sovereign ruler. He was a vassal of the Mughal emperor, an upper-level Mansabdar, or a high-ranking official of the administration, who was paid for his services by the allotment of Jagirs. He held his Vatan Jagir, or hereditary dominion, that was retroactively called Jaipur. He also held various other Jagirs that were granted to him by the emperor from time to time. He came to the throne of Amber (pronounced Aambeyr) in 1699. In 1702-3, when a mere lad of 14, he participated in Aurungzeb's war campaigns against the Marathas and acquitted himself well. His epithet Sawai literally meant 'one and a quarter' and was used to distinguish him from his illustrious ancestor of the same name who was called Mirza Raja. (The two Jai Singhs have often been confused.)

Jai Singh came of age at a time when the once mighty Mughal empire had started losing ground. His own rise in the court hierarchy was in direct proportion to the weakening of the central power. During 1712-37 he served variously as the governor of the provinces of Agra and Malwa. He was dismissed from both the posts in 1737. Jai Singh received huge funds from the emperor for enlisting troops against the Marathas, which he divided between the Marathas and himself and preferred to spend his time at his capital. He had dreams of making his own peace with the Marathas and carving out a vast independent kingdom for himself. He failed in both the missions, but in 1727 built a new capital, named after himself.

In its heyday, the Mughal empire came up with spectacular buildings and gardens. In the reign of the later, lesser Mughals, the cultural activity, in keeping with the general atmosphere of intrigue, became Haveli or mansion-oriented. The pastimes of the nobility in this period were degeneracy, music and poetry. Jai Singh was an exception. Though not averse to intrigue, he was inspired by the earlier illustrious Mughals rather than by his own contemporaries. It is significant that Jai Singh's observatories were the only visible astronomical effort in the whole of the Sultanate and Mughal periods.

Jai Singh's interest in astronomy was no doubt genuine. But astronomy was also his refuge, and probably a political statement, too. The year 1720 was a year of rejoicing for Muhammad Shah, because he had just freed himself from the clutches of the king-makers. A grand darbar was held on 25 November 1720, where Jai Singh successfully pleaded for the abolition of Jazia, the hated tax on Hindus. It was probably at this darbar (or when Jai Singh attended the imperial court a few months later in July 1721) that Jai Singh took the royal permission for building his observatory. The Delhi observatory in a way commemorated the re-establishment, with Jai Singh's support, of order if not leadership, at Delhi after years of anarchy. In a similar manner, Jaipur and its observatory symbolized Jai Singh's own imperial dreams. There was an element of irony in Jai Singh's nomenclature for his astronomical work. *Zij-e-Muhammad Shahi* (completed 1728) was probably the only genuine tribute Raja Jai Singh ever paid to his ineffectual but charming emperor.

From a scientific point of view, the most remarkable feature of Jai Singh's astronomy was its anachronism. When he came on the scene, the telescope had been in use in Europe for over 100 years. Observatories had been set up at Paris and Greenwich, and many important discoveries made. The telescope was a revolutionary break from the past. It freed astronomy from the physical limitations of the eye, and was therefore an instrument of the future. Brass and masonry instruments, on the other hand, were a dead end even if they were no worse than the earliest telescopic instruments. Jai Singh failed to recognize the significance of European developments. There was not an iota of doubt in Jai Singh's mind that he need not look beyond Samarqand for inspiration. To him, European astronomers were Europe's Ulugh Begs, and as a conscientious researcher, he sought to compare his own results with theirs.

Accordingly in 1728, when Jai Singh's own observational tables were finally ready, he sponsored a scientific delegation to Portugal. Led by the Jesuit priest Father Emmanuel de Figueredo, the head of the Jesuit mission at Agra, the delegation left in 1728 for Lisbon and returned a year and a half later in 1730, armed with mathematical books and some instruments, presumably telescopes. He tried the imported instruments and found them wanting. Most importantly, the delegation brought back Philippe de la Hire's (1640-1718) rather inconsequential *Tabulae Astronomicae.* These tables were prepared at the Paris observatory and originally published in 1687 with a revised edition coming out in 1702. They were enthusiastically received at Jaipur and promptly translated. Although most of the data in Jai Singh's tables were probably his own, he did borrow from their refraction corrections, geographical coordinates of a number of places, and probably the equation of time. Very soon it was discovered that Hire's tables were not the last word. At places, they did not match the observations. Using the terminology he was familiar with, Jai Singh attributed these discrepancies to the 'inferior diameter' of Hire's instruments.

Jai Singh then invited Jesuit priests from the French factory (fortified warehouse) at Chandernagore in Bengal for consultations. Father Claude Boudier (1686-1757) accompanied by Father Francis J. Pons (1698-1752) arrived at Jaipur in 1734 and confirmed that Hire's tables were indeed defective. Jai Singh also arranged for the visit of two Jesuit mathematicians from Europe, Father Anton Gabelsberger (1704-41) and Andreas Strobl (1703-52), who arrived in Jaipur in 1740. Jai Singh planned to send another delegation to Europe but his death in 1743 put an end to his plans.

Jai Singh's choice of Portugal for scientific consultancy was ill-conceived. Its riches had come a long time ago, in the pre-Galilean era, and gone into Mughal-style pomp and extravagance. Devoid of any scientific credentials whatsoever, Portugal was in no position to offer any enlightenment to Jai Singh, not because it was Catholic but because it was a nobody. The eighteenth century belonged to France and England, which were engaged in bitter commercial and naval rivalry. Both were great patrons of astronomy because of its utility as a valuable navigational aid. Astronomy became a fashion among the new rich in Europe. It might have been possible for Jai Singh to emulate the European rich and acquire from Paris or London some good-quality instruments and use them visually. Or, using his position at the imperial court, he could have asked for and received astronomical instruments as gift from any of the trading companies. Even European sailors and traders would have found it profitable to sell their astronomical instruments to Jai Singh and even educate him on their use, if he had so wished. It would certainly have been a rewarding experience; he would have been the first modern astronomer to systematically survey the southern skies.

The scientific climate of eighteenth century India stood in sharp contrast to the one in France and England. Europe needed modern astronomy and therefore developed technology for its sake. Traditional craftsmen were persuaded to make the much needed precision instruments in collaboration with the astronomers themselves. A turning point in history does not look for precedents. Jai Singh's India, on the other hand, had no use for astronomy, modern or medieval. Astronomy here was no more than a pastime and was therefore pegged at the available technology. When Jai Singh could not get the desired brass instruments made, he tamely gave in and fell back on masonry, in keeping with the long Indian tradition of building imposing palaces, temples and mosques.

Jai Singh's edifice of science did not survive for long. In 1745, two years after Jai Singh's death, Emperor Muhammad Shah invited Father Strobl to come to Delhi and take charge of the observatory. He declined. In 1764 the observatory was severely vandalized, when Javahar Singh, son of Ṣuraj Mal, the Jat Raja of Bharatpur, plundered Delhi. More than 150 years later, the then Maharaja of Jaipur perfunctorily renovated the observatory to give it a presentable look at the time of the 1911 Delhi darbar of King George V. (The Delhi and Jaipur observatories were then in a rather dilapidated state and no more than popular tourist spots.) Perhaps the most telling commentary on Jai Singh's dedicated but largely irrelevant scientific enterprise came from the rather disconcerting fact that his grandson converted the Jaipur observatory into a gun factory, and used his ancestral 400 kg brass astrolabe for target practice.

VI. ADVENT OF MODERN ASTRONOMY

It is significant that the first British merchant ship reached India the same year as the telescope was invented in the Netherlands. The needs of the maritime trade acted as a great incentive for growth of modern astronomy. Observatories were set up at Paris (1667) and Greenwich (1675) to solve the problem of the longitude at sea, and many young men seeking employment with the (British) East India Company took tuition from the Astronomer Royal. It paid to join the Company, and it paid to know astronomy. Modern astronomy came to India in tow with the Europeans. With the post-Aurungzeb (1707) collapse of the Mughal empire, the overseas Vaiśya (commercial) outfits developed Kṣatriya (territorial and martial) ambitions and got down to the task of acquainting themselves with their future empire, using astronomy as an aid. (Note that even though the Mughal emperors received spectacles and binoculars as gifts, and Jai Singh half-heartedly used a telescope, these instruments remained scientific dead ends in medieval India.)

Ironically, the earliest recorded use of telescope in India was in the field of pure astronomy rather than in applied, and thus belongs to the realm of romance of history rather than its compulsions. The observer was an Englishman, Jeremiah Shakerley (1626-55), who was one of the earliest followers of Kepler and viewed the 1651 transit of Mercury from Surat in west India. He could, however, time neither the ingress nor the egress. His observation therefore was of no scientific use and remained a curiosity. More representative of the things to come was the work of the Jesuit priest Father Jean Richaud (1633-93), who in 1689 discovered from Pondicherry that the bright star Alpha Centauri was in fact double. Thanks to the dedicated work of the Jesuits, who had the training, the time, and the opportunity of criss-crossing the country, the French in India were more successful on the scientific front than on the colonial. The first reliable map of India was compiled by the French geographer Jean-Baptiste Bourguignon D'Anville (1697-1782), whose 1737 map of south India was based on the field work done in 1719 by the Jesuit Father Jean-Venant Bouchet (1655-1732).

The early use of telescopic astronomy in India was desultory, sporadic and often motivated by personal curiosity. Things changed with the 1757 battle of Plassey which transformed the Company into a Jagirdar. In 1764 Major James Rennell (1742-1830) was appointed the Company surveyor. Astronomy was now pressed into the service of the new state, for surveying the acquired lands and for carrying out route surveys in the interior for planned military conquests. The 1761 and 1769 transits of Venus occurred at the right time. Perceived as a continuation of the on-going rivalry between France and England, they brought many instruments and a general awareness of astronomy to colonial India. What, however, led to the institutionalization of modern astronomy in India was not the love of stars, but rather the fear of the Coromandel coast. Rocky and full of shoals, and hit by two monsoons a year, India's east coast became the graveyard of many a sailing ship. Its survey literally became a matter of life and death. Accordingly, a well-equipped, trained surveyor-astronomer Michael Topping (1747-96) was brought from England to Madras in 1785. Next year, perhaps more by design than chance, there came up at Egmore in Madras a small private observatory. Its founder was William Petrie (d.1816), an enlightened and influential Company officer, who later officiated as the Governor of Madras for a few months, and finally served as the Governor of the Prince of Wales Island (Penang, Malaysia).

It was not the first time that an enterprising Company officer had set up an observatory in his sprawling garden house. The significance of Petrie's observatory lay not so much in what it achieved but to what it led. It was used by Topping as a reference meridian. On Petrie's persuasion the observatory was taken over by the Company in 1790. Two years later the observatory moved to its own campus at Nungambakkam in Madras, where some of its old remnants can still be seen. A hundred years later, in 1899, astronomical activity was shifted to Kodaikanal. One of the instruments that Petrie bequeathed to the observatory was a pendulum clock by John Shelton. Presumably made for the 1769 transit of Venus and identical to the one used by Captain James Cook in his voyages, it is still ticking at Kodaikanal, a witness to the advent and growth of modern astronomy in India.

With the destruction of Tipu Sultan of Mysore at the 1799 battle of Seringapatam, the Company's territories extended from the east coast to the west. Just as Plassey had produced its Rennell, Seringapatam produced its Lambton, only more quickly. Brigade-Major, William Lambton, who had earlier done survey work in New Brunswick, Canada, started work in 1800 on the trigonometrical survey of peninsular India, using second-hand instruments bought within the country. On 1 January 1818 the survey was extended to cover the whole country and beyond, under the project title the Great Trigonometrical Survey of India (GTS). In 1878 it was merged with the secondary surveys to constitute the Survey of India. Both the names are often used retroactively. Thus, the end of the eighteenth century saw the introduction of modern astronomy in India as a colonial aid.

In the nineteenth century there was widespread use of science by the British to further their commercial and political interests. Indians came into contact with modern science, when they were assigned the peripheral role of providing cheap labour. Once introduced to modern science, Indians finally strove to become full-fledged members of the international republic of science in their own right.

Critique

Astronomy, to quote the German poet Heinrich Heine (1797-1856), is the 'old ever-young' science. It originated in man's endeavour to understand his cosmic environment and to benefit from this understanding. The whole history of astronomy has been the result of interplay of two factors: utilitarian and cultural. At critical junctures in its history, astronomy received impetus for its ability to successfully negotiate human fear of natural forces: the fear of gods in ancient and medieval times, the fear of high seas in renaissance Europe. Whenever cultural areas felt self-assured, they advanced astronomy. Having secured their place on the earth, these cultures sought to be the ones to unravel the mysteries of the heavens. There was thus a remarkable correlation between a culture's gross national product and its astronomical activity. At any given point of time, the culture that had been materially the most prosperous had also been astronomically the most active. We could thus trace the migration of the astronomical centre of gravity down the ages; Babylon and Greece, through India and west and central Asia to Europe, and, finally the USA in the present century.

In earlier times society lent its support for astronomy for calendrical and astrological reasons. Since ancient man felt insecure on Earth, he felt scared of the gods also. While the members of a tribe could put their faith in their chieftain, the chieftain himself needed a source of strength and legitimacy which could have only come from above. Heavenly bodies were perceived as the channel through which the Almighty would communicate with the chosen ones on the Earth. It was therefore essential to keep track of the celestial objects and intercept and interpret divine signals supposedly emanating from then. This specialist job gave rise to the class of astronomer-astrologers, which came to wield tremendous influence in human society.

As astronomical knowledge increased, astrology also became more intricate. Also, as the social structure became more complex, more and more people laid claim to a right to receive divine signals and guidance. Belief in astrology thus kept astronomy alive. The only lean period astronomy experienced in India was when Buddhism held sway. This was so because Buddha taught against astrology. Otherwise all kings, ancient or medieval, Hindu or Muslim, were believers in astrology, no doubt because of the risks and uncertainties that went with wearing the crown.

Modern science rightly dubs astrology as a pseudo-scientific cult. It will however be wrong to backdate this pejoration and condemn earlier astronomers for practicing astrology, belief in which came naturally to people, consistent as it was with the then prevalent cosmos-view. First doubts about astrology appeared in Europe when printing was introduced and it became possible to inter-compare astrological predictions which until then had remained localized and absolute.

While discussing earlier times, it is important to place ourselves in the relevant time-frame. We may therefore preferably use a value-free term like Astronomism to denote the unselfconscious practice of astronomy-astrology of yesteryears. An astronomer-astrologer of earlier times could then be designated an Astronomist.

The early awe of astronomical gods left its mark on the Siddhāntic period. Varāhamihira and Brahmagupta, while giving scientific theory of the eclipses felt duty bound, as it were, to preserve and propagate antiquated concepts, even knowing them to be wrong.

It is remarkable that the Vedic texts and Purāṇas were full of speculation on all topics under the sun and beyond. In contrast, the Siddhāntic texts most meticulously confined themselves to mathematical work and desisted from scientific enquiry. For example, the physical statement of heliocentrism of the inner planets was but a short step ahead of the Siddhāntic treatment, but was left unsaid. Perhaps the Siddhāntic astronomers did not want to stick their neck out and make explicit statements that ran counter to what was said in the scriptures. One wonders whether the society's support for astronomy in the name of astrology prevented the astronomers from challenging the existing paradigms.

In earlier times, astronomical knowledge was not treated as scientific deduction, but as divine revelation. Its dissemination was accordingly patterned after *Ṛgveda*. Astronomical results were presented in terse ślokas, where rigours of metre often led to lack of clarity and the possibility of more than one interpretation. And since in the absence of a mode of writing, knowledge had to be transmitted orally, after a few generations of pupils, many scientific works were reduced to merely a collection of ślokas, left dangling without context and beyond criticism.

A telling illustration was the modification of a verse in the *Āryabhaṭīya* with a view to removing any reference to Āryabhaṭṭa's belief, correct as it was, in Earth's daily spin.

Āryabhaṭīya closes with the following verse:

> This work, *Āryabhaṭīya* by name, is the same as the ancient *Svayaṁbhūva* (which was revealed by Svayaṁbhu) and as such it is true for all times. One who imitates it or finds faults with it shall lose his good deeds and longevity.

It has been argued that a radical like Āryabhaṭṭa could not have made such a retrogressive statement, which therefore must be a later interpolation. This may well leave Āryabhaṭṭa's personal reputation intact, but does not speak very high of his followers, who apparently unwilling or incapable of defending Āryabhaṭṭa's work decided to intimidate the present and future critics with curses.

How a purely scientific work was slowly made extra-scientific was illustrated by the reaction of Bhāskara-I, a great authority on Āryabhaṭṭa. Bhāskara-I believed that science of astronomy contained in *Āryabhaṭīya* was acquired by Āryabhaṭṭa by the grace of god Brahma, because (Bhāskara-I maintained) the knowledge of laws governing the planetary phenomena could not be acquired by any individual by observations made during his lifetime.

Similarly a legend had grown around the sixteenth century Siddhāntic astronomer Gaṇeśa Daivajñā. According to it, Gaṇeśa's father Keśava on being ridiculed by the king for his failure to accurately predict an eclipse prayed to lord Gaṇeśa who agreed to be born as Keśava's son. The legend, built on the astronomer's proper name, probably added to the market value of his almanac, but could hardly have strengthened the spirit of scientific enquiry.

A remarkable feature of pre-telescopic astronomical activity in India was its interaction with the outside work. In the post-Vedānta period, there were clear signs of input from the Graeco-Babylonian world, flowering into the rich Siddhāntic tradition. it was believed that advancement in trigonometry in the seventeenth and eighteenth centuries at the hands of astronomers in north India was due to the influence of the work of Ulugh Beg's Samarqand school.

The Zij period had begun in Baghdad with the translation of Sanskrit texts. It came to a close at Delhi and Jaipur with the translation of Ulugh Beg's tables into Sanskrit.

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CHAPTER VII

Glimpses of Astronomy in Medieval India

S. A.H. Rizvi

I. ASTRONOMY IN MEDIEVAL TIMES

Astronomy started developing with the dawn of civilization. The curiosity about the heavenly bodies and their movements prompted the ancient man to become a stargazer. He observed throughout the year the changing patterns of sunrise and sunset, the phases of the Moon, the regular motions of Moon to the left among the stars at different altitudes of culmination but at about the same speed, the seasonal appearance and disappearance of some constellations, and the more complex motion of the morning and evening stars and other planets. He was aware in many ways of the march of time, of the Moon, of meteorologic seasons, and years. He made for himself calendars wherein those events were foretold on the basis of past experience—calendars based on meteorologic events, on the Moon cycle, or the Sun cycle. The results of these observations, in the early stages might have been purely practical, empirical, too raw or rough, but over a period of centuries man attained more and more knowledge and gradually improved observations from which the derived results were refined, and he tried to understand more about the secrets of the Universe. But the progress of this science was considerably slow and it took thousands of years to reach to the level of Siddhantic texts. Perhaps this was because, as Sarton[1] said, the growth of science was always entangled in psychological and social accidents.

The Siddhantas

The period of Sulbasutras was followed by the age of the Siddhantas. As Al-Beruni noted, there were five Siddhantas, namely, Surya-siddhanta (i.e. the siddhantas of the Sun), Vasishtha-siddhanta, Paulisa-siddhanta, Romaka-siddhanta and Brahma-siddhanta. According to Brahmagupta,[2] many of the Siddhantas were Surya-siddhantas, others were Indu, Paulisa, Romaka, Vasishtha and Yavana (i.e. the Greek) siddhantas; and though the siddhantas were many, they differed only in words, not in the subject matter. Any one who studied them properly would find that they agreed with each other.

Varahamihira (fl. AD 505), was a scientist of rare merit, who despite his regard for ancient traditions and sages, always followed the scientific method. In view of his extraordinary and masterly treatment of the subjects of astronomy and astrology in all their ramifications, he was held in high esteem by scholars of ancient and medieval India. About his greatness Al-Beruni said: 'Varahamihira has already revealed himself to us as a man who accurately knows the shape of the world...On the whole his foot stands firmly on the basis of the truth and he clearly speaks out the truth.' Varahamihira composed Tantra or mathematical astronomy which he called Karana; Utpala and Al-Beruni referred to it as Pancha Siddhantika apparently because it epitomized the salient features of the five siddhantas current in their time.[3] Varahamihira explained in this siddhanta the systems followed by, among others, the early version of Surya-siddhanta, a famous work which has come down to us only in a much later version.[4] There was no doubt that Surya-siddhanta was considered to be the most accurate. Its parameters were corrected and additions made in later centuries. In fact, this took place in the ninth or tenth century AD or even later.[5] This astronomical treatise was widely accepted and followed in India, and, according to Sen,[6] was one of the earliest of the Hindu scientific astronomical works which began to take shape from about the fourth or fifth century AD, at a time when old astronomical ideas and calculations came to be revised and placed on a move scientific and mathematical basis.

Al-Beruni, besides some modern writers like Burgess and Whitney, believed that the scientific aspects and parameters of the Surya-siddhanta were based on Greek astronomical sources. Observational astronomy in India had not developed to such an extent as to make possible generation of data, indispensable for such computations and improvements upon them from time to time. In their view, Hindu astronomy, was an offshoot from Greek, planted not far from the commencement of the Christian era, and attaining its fully developed form in the course of the fifth and sixth centuries.[7]

Kedardatt Joshi[8] in his commentary on *Grahalaghavam* of Ganesha stated that Varsh was in contact with the Yavanas and referred to a Sanskrit Sloka from *Brihat Samhita* (ii.14) in which Varsh compared Yavanas with Indian sages: 'Yavanas are Mlechcha, this science (Jyotisa) is well established among them, (therefore) even they are worshipped like sages, how much more then would a twice-born proficient in astrology be?'[9]

Varahamihira used as many as 34 Sanskritized Greek words in his *Brihat Samhita*, and according to Ajay Mitra, 'The Romaka and Paulisa are direct Sanskritized importations from the West, while the evidence set forth above merely indicates Indians' acquaintance with Greek astronomy and astrology and at best as exchange between the two.' But Swami Vivekananda argued,[10] 'There may be, it is true, some similarity between the Greek and Indian terms in astronomy and so forth, but the westerners have ignored the direct Sanskrit etymology and sought for some far-fetched etymology from Greek. That such shallow and biased learning has been manifested by many orientalists in the West is deplorable. From a single Sanskrit Sloka that reads, "The Yavanas are Mlechchas, in them, this science is established, therefore, even they deserve worship like Rishis...", a true reading of the Sloka may show that the Mlechcha disciples of the Aryans are herein praised in order to encourage them to a further study of the Aryan sciences...' But common sense must support the idea that there were a host of influences between society and its sciences, and it proves very difficult to trace these influences in concrete form.

Later Siddhantas

The later siddhantas were generally based on the earlier ones but were improved upon. The *Aryabhatiya* of Aryabhatta (*c.* AD 499) was the earliest one covering astronomy and mathematics with no logic or deductive methodology, as could be seen in the work of Ptolemy. It consisted of astronomical constants and the sine table, division of time and rules for computing the longitudes of planets using eccentrics and epicycles and computation of eclipses.

The next important astronomical work was the *Brahma-sphuta-siddhanta* of Brahmagupta (b. AD 598), considered to be the most influential book on the subject. Its contents were classified into 24 chapters dealing with the nature of the globe and the figure of heaven and earth, revolutions of the planets, calculation of time, method of finding the sine of an arc, correction of the places of the planets, lunar and solar eclipses, shadow of the moon, meeting and conjunction of the planets, latitudes of the planets, etc.[11] In this text rules were taken from previous Siddhantas. Brahmagupta himself stated rules[12] regarding the mean motions of the Sun and the Moon, the Moon's apogee and node, as also the mean motions of Mars, Mercury's sighra, Jupiter, Venus's sighra and Saturn from Lata (author of Surya-siddhanta); elapsed years and revolution of the Yuga from Vasishtha-pada of Vijayanandin's work; and rules about apogees, nodes, epicycles and true motions of planets from Aryabhatta. Srisena transformed the Romaka and other classics.

Siddhantas in Medieval Times:

During medieval period the above noted Siddhantas were treated as texts for practicing astronomers. In fact the middle ages did not witness any revolution in science, at least not in the sense we have come to associate with certain features of the combined achievement of men like Copernicus, Kepler, Galileo, Descartes and Newton. But this did not mean that the ideal of innovation was beyond the imagination of medieval scholars or that they lacked a critical attitude towards their admittedly respected predecessors. In medieval Islam the concept of innovation in intellectual endeavour found expression in terms like *istikhraj* or *istinbat* (discovery), which denoted accomplishments that went beyond merely elucidating, amending, or completing an earlier contribution to knowledge; and a critical attitude clearly revealed itself in the not infrequent composition of *shukuk* (aporia or dubitationes), a form of argument in which difficulties or objections were raised against ancient authorities. But it did not mean that their authors did not possess intellectual ambition and independence of mind to a remarkable degree.[13]

During medieval times, generally two categories of astronomical-mathematical treatises were composed: commentaries on the above siddhantas and texts based on them. The authors of such books presented anterior concept, theory, law or principle, but altogether they did express a series of objections and corrections of the earlier data, and sometimes even presented new concepts.

A large number of commentaries on Surya-siddhanta were available and a few of them prepared in the medieval period included those of Madmapila (AD 1374), Paramesvara (AD 1432),Yallaya (AD 1472), Bhudhara Suri (AD 1572), Raghavananda, Cakravartin (AD 1599), Tamma Yajvan (AD 1599), Ranganatha (AD 1603), Kamalakara (AD 1616) and Dadabhai (AD 1720).[14]

In Aryabhatta siddhanta, Aryabhatta formed the basis for Ardharatrikapaksa in Indian astronomy.[15] For planetary revolutions Thibaut[16] compared the values given in the two siddhantas, to which we could add Aryabhatta's values as given in his Ardharatrika system:

	Old SS	*Modern SS*	*Aryabhatta (Ardharatrika)*
Mercury	17,973,000	17,937,050	17,933,000
Venus	7,022,388	7,022,376	7,022,388
Mars	2,296,824	2,296,832	2,396,824
Jupiter	364,220	364,220	364,220
Saturn	146,564	146,568	146,564

Here we observe that while the two siddhantas disagree in all the cases except Jupiter, the old Siddhanta agrees with Aryabhatta.

Aryabhatta discusses Dasgitika, Ganita-pada, Kalakriya-pada and Gola-pada. The text is very brief. It does not discuss as many topics as the later treatises. For example, it is lacking in methods of computing cusps of the moon, conjunction of planets, Tithis, Naksatra, Yogas and Karanas and does not give latitudes and longitudes of stars. There are no algorithms for computing heliocentric rising and setting of planets and their conjunctions, etc.[17] On this work several leading astronomers of the medieval age have put forth their comments and corrections, and many other topics which were neglected earlier have been incorporated. Among them, the earliest commentary was by Bhaskara-I (AD 600) and other commentaries were by Suryadeva Yajvan (AD 1192), Somesvara (eleventh or twelfth century), Nilakantha Somasutvan (AD 1444), Yallaya (AD 1480), Paramesvara (AD 1450), Raghunatha Raja (AD 1597) and Ghatigopa (AD 1800).[18]

The *Brahma-sphuta-siddhanta* of Brahmagupta (AD 628), an astronomical-mathematical work which exerted considerable influence in the renaissance of Arab astronomy in the eight century AD, criticised the views of some of his predecessors, including Aryabhatta and Varahamihira. The commentators of *Brahma-sphuta-siddhanta* were Amaraja, Bhattotpala, Lalla and Somesvara.

The *Siddhanta siromani* of Bhaskara-II (AD 1150) was the most comprehensive siddhanta, and was a widely used work in Indian astronomy of medieval period. The most important commentaries on the two chapters of this siddhanta (i.e. Ganitadhayaya and Goladhyaya) were by Lakshmidasa (AD 1501), Ganesha Daivajna (AD 1522), Narsimha (AD 1621) and Munisvara (seventeenth century).

Nilakantha Somasutvan (AD 1465-1545), the great astronomer of medieval times composed two treatises, namely, *Candrachayaganita* dealing with the method for calculation of time during night from a measurement of the shadow cast by the moon, and *Tantrasamgraha* in which he discussed the conception of time computation of post-kali days, solar and lunar months, calculation of mean solar day, and determination of the orbits of planets in the Hindu geocentric system.

Siddhanta-Greco-Arabic Astronomy

Neugbauer[19] said that the first impact on Islamic science was made by Indian astronomy, shortly followed by direct reception through Greek sources of the Ptolemaic system. This complex origin of Islamic astronomy left its traces wherever its influence spread from Persia to Spain and from Byzantine to Italy, France and England.

The Indian astronomical treatises were transmitted directly to the scholars of Baghdad. The foundation of Islamic astronomy started during the reign of Abbasi Khalifah Al-Mansur (AD 753-74). A copy of *Brahma-sphuta-siddhanta* of Brahmagupta was brought to Baghdad from India by a deputation from Sind in AD 770 and was presented to Al-Mansur and a recension entitled *Sindhind* was prepared by Yaqub ibn Tariq and Ibrahim Fazari. Later, the *Aryabhatiya* was rendered by Abul Hussain Ahwazi into Arabic under the title *Arjbhad*. Another classic, *Khandakhadyka* of Brahmagupta, a popular astronomical work in India, was translated as *Arkand* by Yaqub ibn Tariq. These three important classics remained the basis of astronomical computations for astronomers who used the Arabic medium. According to Saiyyed Sulaiman Nadavai[20] although Ptolemy's *Megale Syntaxis* had been translated into Arabic as *Al-Majisti*, yet for a long time the Arab astronomers from Baghdad to Spain clung to the Indian books of Siddhanta (the *Sindhind*). They composed summaries, wrote commentaries, rectified errors and suggested improvements, right up to the eleventh century.

Al-Beruni (AD 973-1048), who accompanied Sultan Mahmud of Ghazna, was a versatile scholar of Persian, Arabic and Sanskrit. He wrote 27 books pertaining to Indian culture, philosophies and science. When Al-Beruni came to India, he had knowledge of Indian astronomy, acquired by the study of Brahmagupta's siddhanta (the *Sindhind*). In India, Al-Beruni recommenced his study of Indian astronomy, not from translations but from Sanskrit originals. He tried, with the help of learned pandits to translate the work of Brahmagupta. He translated many astronomical texts from Sanskrit into Arabic. These included *Tarjumat Palisasiddhanta* of Brahmagupta, *Tarjumat ma fi Brahmasiddhanta min turuq al-Hisab*, *Tarjumat* *kitab al-Mawalid al-saghir li- Barahamihr, Kitab fi illat tasnif ul-ta'dil 'ind ashab al-Sindhind,* and *Tahdhib zij al-Arkand.*[21] He also wrote a few books for Hindus from Arabic,[22] like *Tarjumat kitab al-Majasti li-Batlamiyus, Tarjumat kitab fi usul al-Handasa li-Uqlaydas* and *Tarjumat kitab fi'l-usturlab li-Abi Rayhan al-Beruni.*

However, Al-Beruni acted like an embassy for transmitting mathematical sciences between Hindus and Muslims.

Greco-Arabic and Persian Astronomy in India

During the middle ages astronomy was considered to be the most important of mathematical sciences. Al-Beruni made an effort to introduce Greco-Arabic astronomy in India, at the level of scholars, through translations into Sanskrit. But it appears that the first Indian monarch who introduced astronomy from Arabic into India was Emperor Iltutamish (AD 1210-35). He got Fakhr Al-Din M.b.Umer Al-Razi's (d. AD 1209) treatise *al-Sirr al-maktum fi munkhatabat fi ilm al-falak wal-nujum* (the hidden secret in the description of science of heavens and stars) translated into Persian as *Tarjumah Sirr i maktum.*[23]

Firoze Tughlaq (AD 1351-1388) selected a Sanskrit work *Brihat Samhita* of Varahamihira for translation into Persian. He entrusted this task to the court chronicler Abdul Aziz Shams bin Baha Nuri Dehlavi, who translated the Sanskrit text according to Bhattotpala's commentary and called it *Tarjuma-e-Barahi Sanghita.* But in this translation eight chapters which were of a religious nature were removed. Another court astronomer of Firoze Tughlaq, Mahendra Suri in 1370 introduced into Sanskrit some astronomical principles based on Arabic and Persian sources. He called his work *Yantraraja,* in which he mentioned: 'Various treatises on yantra have been written by the yavanas in their own language according to their own intellects. Having gone through them like the ocean, I shall here speak of the essence of them all as the nectar.'[24] It may be noted here that the meaning of yavana, as Datta pointed out,[25] was Persian and not Greek. However, Abdi says,[26] 'It is a pity that the movement started by Mahendra Suri could not gain momentum.' Not many commentaries were composed on *Yantraraja*—only two, one by his own disciple Malayendu Suri (AD 1378) and 464 years later by Sudhakar Ḍvivedin. Had the earlier tradition been followed and the movement been successful, there was a possibility of the siddhantic and Persio-Arabic systems being welded into a common system of Indian astronomy. However, Greco-Arabic and Persian astronomy continued to flow in India. The popular works were of Abdul Hasan Abad Al-Rahman bin Umar Al-sufi Al-Razi (AD 903-86), Mahamud bin Muhammad bin Umar Chaghmini (d. AD 1221), Abu Jafar Nasir al-Din Muhammad bin Muhammad bin al-Hussain Al-Tusi (AD 1201-74), Salahud-Din Musa bin Muhammad Qazizadah Al-Rumi (d. AD 1431-2), Alaud-Din Ali bin Muhammad Qushji (AD 1438-74) and Baha al-Din Muhammad bin Abdus Samad al-Harisi al-Amuli (AD 1547-1621). The works of these astronomers provided the basic material to Indian astronomers for training in the Ptolemaic system and the rules of astronomical computations. The result of the study of these works was that a large number of commentaries, simplified recensions and some compendiums based on them were composed by Indian astronomers. This was in fact the outcome of creative handling of numerous sources and a different way of exposition with the aim of achieving uniformity, exactness, formulation of problems and their easy solutions, and sometimes they posed new concepts or refuted the earlier ones.

The first probably Arabic astronomical treatise which was introduced during medieval times in India was *Suwar al-Kawakib* (the shape of luminaries) of al-Razi, which was prepared in AD 960. But later on, when Persian became the language of scholars, a Persian translation with commentary was made by Lutf Allah Muhandis bin Ahmad Nadir Memar Lahori Dehlawi in AD 1681.

The most popular and current treatise in medieval India was Nasir al-Din al-Tusi's *Tahrir al-Majisti*, an improved recension of Ptolemy's *Megale-Syntaxis*. Al-Tusi's work ranged wide over all branches of mathematical sciences and philosophy. The Maragha observatory was constructed under his directorship.[27] He prepared *Zij Ilkhani* based on observations taken at this astronomical observatory in AD 1271. Al-Tusi composed another important book *Tadhkira*, which was the main source for the study of his astronomical ideas. In this famous and influential book, he discussed the hypothesis of Ibn Haitham. It would not be out of place to note that Ibn Haitham raised a series of *shukuk* or objections against certain aspects of Ptolemaic astronomy, in particular on what appeared to him as an inconsistency generated by Ptolemy's introduction of the equant hypothesis.[28] Perhaps *Tadhkira* was the main source for inspiring the Indian astronomer-philosophers to consider critically the validity of the Ptolemaic system and some of them raised serious doubts about that as well.

Khair Allah Khan, an associate of Sawai Jai Singh prepared a Persian translation of Al-Tusi's *Majisti* under the title *Taqrib al-Tahrir* in AD 1747. Jagannatha Samrata also wrote *Samrat-siddhanta*, a Sanskrit version of *Majisti* from Arabic. Ismatullah Saharanpuri had composed a commentary in Arabic entitled *Sharh Tahrir al-Majisti*. He also prepared a Persian commentary on *Tashrih al-aflak* of Baha al-Din Amuli entitled *Sharh-i-Tashrih al-aflak* in AD 1670, in which he discussed orbits of planets and their motion with special reference to India.

There were many other astronomers of medieval India who contributed to this subject. Farid al-Din Masud bin Ibrahim Dehlawi (d. AD 1629), a court astronomer of Shah Jahan, wrote *Siraj al-istikhraj*, and Pandit Raj Nemdhar composed in AD 1789-90, *Dil Pasand* and dedicated it to Nawab Amir al-Daulah of Tonk. Rajah Ratan Singh Zakhmi (AD 1782-1851) wrote *Hadaiq al-Nujum*.

A noted mathematician and astronomer of the early nineteenth century was Ghulam Hussain bin Fath Muhammad Karabalai Jaunpuri (AD 1790-1862). He wrote four treatises and a compendium in astronomy: (i) *Anis al-ahbab fi bayan masail usturlab*, composed in AD 1818-19 (ii) *Istilahat al-taqwin* (iii) *Jame Bahadur Khani* (AD 1835); and (iv) *Zij-i-Bahadur Khani*, composed in AD 1825-6. The *Jame Bahadur Khani*, which had been called an encyclopedia of mathematical sciences, was dedicated to Raja Bahadur Khan of Tikari. While writing this book, Ghulam Hussain, by way of an apology, said: 'Since the time of al-Barjandi no comprehensive book dealing with astronomy and allied sciences and at the same time matching with *Almagisti* and commentaries on *Tadhkirah* of Nasir al-Din al-Tusi has appeared in Persian language.... so I undertook to write this work.' The treatment of astronomy in this book was thorough and it presented a comparative study of astronomical data. The author also gave a general account of the science of the spheres, inferior elements, and the nature of stratification of these bodies; the instruments for observing and the methods of observation of particular forms of sphere, the nature and quantities of their motion according to the rules of observation, and finding of mean and equable motion; the form of the Earth and its elevation; and the knowledge of distances and magnitudes. He also explained the foundation and elements of astronomical tables and the technical terms used in an almanac. And finally, he talked about the differences that exist among the observations made by different astronomers.

It may be noted here that during the medieval period the Greco-Arabic and Persian astronomy was fully introduced in India and, as a result of studies in the later part of period, in India astronomers finally came to shift from Ptolemaic and siddhantic theoretical geocentric systems to the experimental heliocentric system.

II THE PLANETARY THEORY

Aristotelian-Ptolemaic-Siddhantic Model of Planetary Motion

Ancient star gazers might have gained the notion of circular motions of planets through the observation that the Sun, Moon and other stars always moved from east to west in circles parallel to each other; and that these bodies began rising from below the Earth and gradually rose to their highest points and then began to decline downwards until they finally disappeared behind the Earth. And they observed this cycle of rising and setting of heavenly bodies every day.

The Pythagoreans postulated that the celestial bodies had spherical shapes and that they moved along circular paths, or as if they were attached to spheres. The Earth, naturally enough, was supposed to be immobile in the middle of all, its centre being the centre of the Universe. The movement of all spheres was uniform, like that of the heavens. However, Pythagoras explained this phenomenon by saying that the planets can not be 'errant' bodies and so must have circular and uniform movements of their own.[1]

Aristotle gave a mechanical and tangible explanation of planetary movements. According to him:[2] 'The universe is spherical and finite, it is spherical because the sphere is the most perfect shape, it is finite, because it has a centre, the centre of the Earth, and an infinite body can not have a centre. There is but one Universe and that Universe is complete, there can be nothing (not even open space) outside of it.' However, Aristotle's views were rejected later but remained an active albeit defensive belief until the eighteenth century.

This Aristotelian concept of the geocentric Universe was elaborated and systematized after more than 400 years by Ptolemy (*c.* 150). He made an essential modification in this scheme. In the first place, he displaced the Earth somewhat from the centre of the deferent circle, so that he had eccentric orbits; and, in addition, he introduced rotation of planets in an epicycle, a secondary, smaller circle. This model in terms of accuracy was a great step forward, indeed the best representation of planetary motion before Kepler.[3]

To understand the Ptolemaic system, consider a geocentric model: a planet moves on the circumference of a circle (the epicycle) whose centre moves in the circumference of another circle (Fig.1). If the Earth was at the centre C of another circle, the system was concentric but if the Earth E did not coincide, then the system was eccentric and the planet could then move uniformly with respect to the point Q called the 'equant'; and this point was chosen along a diameter of the circle containing E and Q in such a way that EC = CQ. Thus, a moving planet along the circle made a uniformly increasing angle.

In this way Ptolemy achieved accurate representations of planetary motions, but of course the device was only kinematic and made no effort to answer the questions in dynamics raised by non-uniform circular movements.[4]

Siddhantic astronomical texts did not say that the planets were going round in ellipses; they said that the planets went in an epicycle, whose centre moved along the mean circular orbit from west to east. Bhaskara said,[5] 'The centre of the celestial sphere coincides with the centre of the earth. The circle in which the planet goes, does not have its centre coinciding with the centre of the earth.' However, Hindu astronomers were using the epicyclic and eccentric theories under geocentric model.

But the studies of Ramasubramanian and others[6] revealed that the astronomers of the school during medieval times modified the conventional planetary model of Indian astronomy and presented the heliocentric model. Paramesvara (1380-1460) suggested in his commentary on *Aryabhatiya*[7] that the Sighrocca of an interior planet in a conventional planetary model should be identified as the planet itself and the mean sun taken as the Sighrocca for all the planets, while computing the sighra correction. Further, he noted that the orbits of Mercury and Venus did not circumscribe the Earth. These ideas were exploited

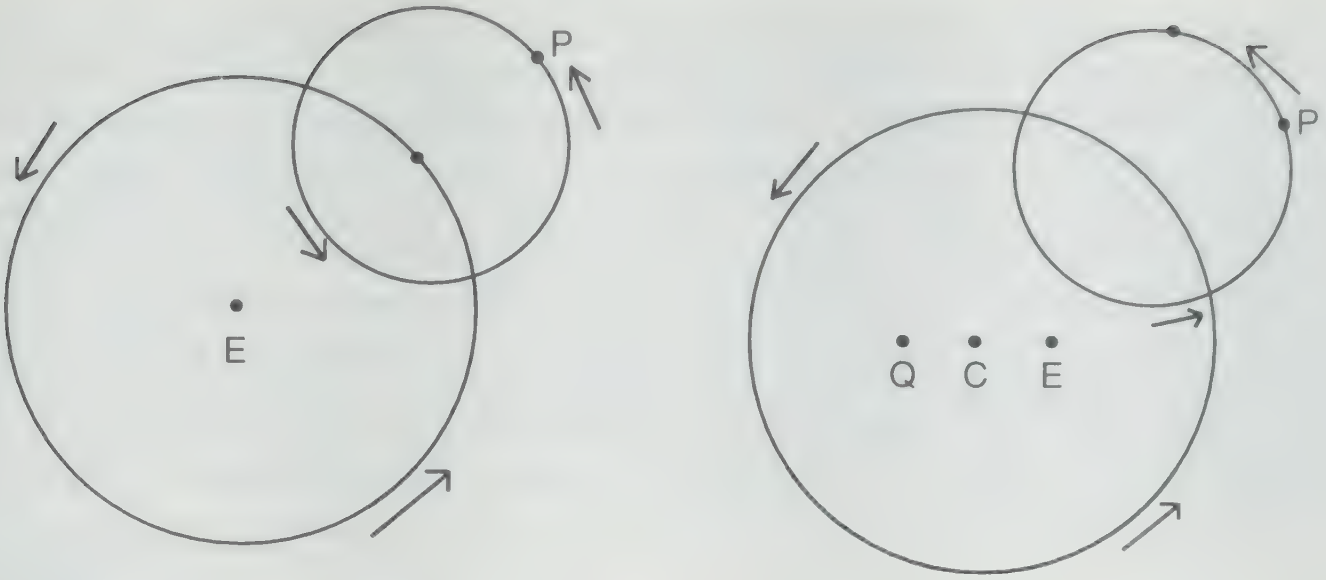
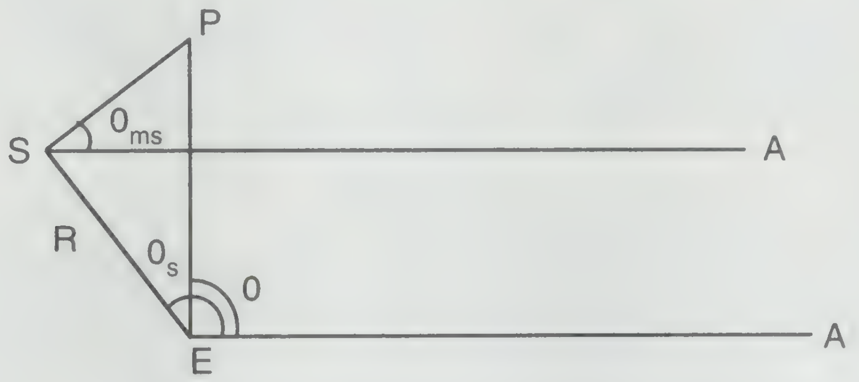


Fig. 1

and formulated later on by the great astronomer of Kerala, Nilakantha Somasutvan (1444-1550), who presented a new planetary model in his works *Golasara, Siddhantadarpana* and *Aryabhatiyabhashya.*

It would not be out of place to mention that in the older Indian planetary model, there were different rules for computing the latitude of interior and exterior planets. But Nilakantha suggested one rule for all the planets, either exterior or interior.

According to Nilakantha the mean sun should be taken as the Sighrocca for interior planets also just as in the case of exterior planets. If P is the Manda corrected planet, E the earth and S the Sighrocca or the mean sun,



then we have, AES = 0s = Sighorcca (mean sun)
ASP = 0ms = Mandasphuta
AEP = 0 = true geocentric longitude of the planet
SEP = 0 – 0s = Sighra correction.

And from the triangle ESQ, we can get the relation

$$\text{Sin } (\Theta - \Theta_s) = \frac{\text{r Sin } \sigma}{[(\text{R} + \text{r Cos } \sigma)^2 + \text{r}^2 \text{Sin}^2 \sigma]^{1/2}}$$

which is the Sighra correction formula given by Nilakantha for calculating the geocentric longitude Q of the planet.[8]

As regards the heliocentric model, Nilakantha explained the eccentric orbit on which the planets moved (Grahabhramana-vritta) themselves at the same rate as the apsides (Uccagati) on the Manda-vritta (or the Manda epicycle drawn with its centre coinciding with the centre of the Manda concentric). In the case of the Sun and the Moon, the centre of the Earth was the centre of the Manda-vritta. For the other planets—namely, Mercury, Venus, Mars, Jupiter and Saturn—the centre of the Manda-vritta moved at the same rate as the mean sun (Madhyarkogati) on the Sighra-vritta (or the Sighra epicycle drawn with its centre coinciding with the centre of the Sighra concentric). The Sighra-vritta for these planets was not inclined with respect to the ecliptic and had the centre of the celestial sphere as its centre. In the case of Mercury and Venus, the dimension of the Sighra-vritta was taken to be that of the concentric and the dimensions (of the epicycles) mentioned were of their own orbits. Further, here the Manda-vritta (and hence the Manda epicycle of the planets) underwent increase or decrease in size in the same way as the Karana (the hypotenuse or the distance of the planet from the centre of the Manda concentric). This is illustrated in figure 2.

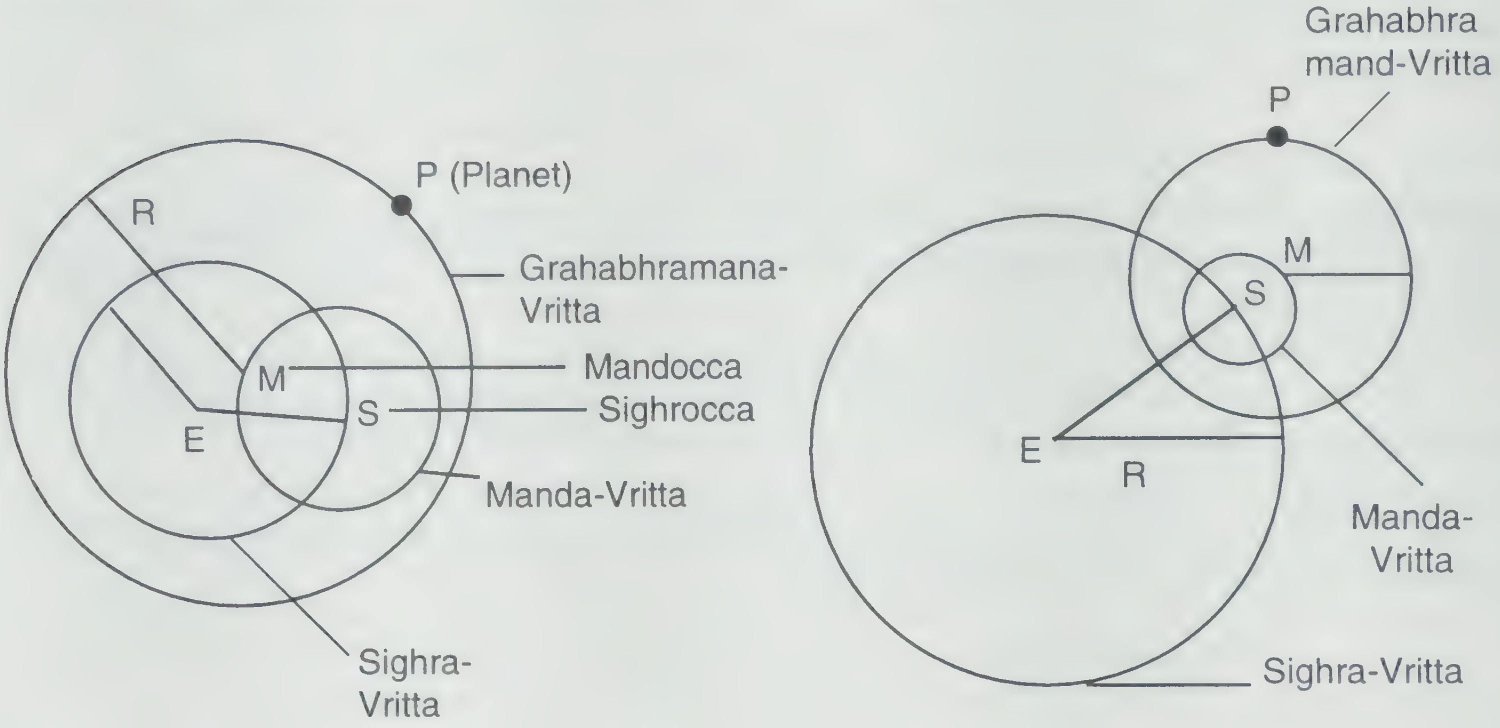


Fig. 2

Further, Nilakantha said in his *Aryabhatiyabhashya*, that the Earth was not circumscribed by the orbits of the interior planets, Mercury and Venus; it was always outside their orbits. Since their orbits were always confined to one side of the geocentric celestial sphere, in completing one revolution they did not go around all the 12 signs (Rasis). For them, mean sun was the Sighrocca. Only their own revolutions were stated to be the revolutions of the Sighrocca. It was only due to the revolution of the Sun (around the Earth) that they (i.e. the interior planets, Mercury, and Venus) completed their movements around the 12 Rasis.[9]

Thus, from the above stated verses, it appeared that in Nilakantha's planetary model, planets moved in eccentric orbits around the Sighrocca, the mean sun going around the Earth, and also planetary orbits were tilted with respect to the orbit of the Sun or the ecliptic.

Nilakantha's planetary model was adopted by the later astronomers of Kerala, namely, Sankaravariyar (1500-60), Acyuta Pisarati (1550-1621), Putumana Somayaji (1660-1740) and others.

Arabic-Copernico-Kepler model

The Arabic astronomers were committed to the Ptolemaic geocentric model of planetary system. The Universe consisted of 13 concentric spheres, four terrestrial and nine celestial. The seven celestial spheres moved with uniform circular velocity round different centres, not coinciding with the centre of the Universe. Each of the seven planets with the exception of the Sun, was studied within an epicycle, which in its turn was fixed in the eccentric and the latter in the main sphere called al-Mumaththal. The sum total of the motions of the Mumaththal together with those of the eccentric and epicycle determined the apparent motion of the planet. The next outer or the eighth sphere was studied with the fixed stars called Falak-uth-thawabit. The ninth or the outermost sphere was called Falak-ul-aflak and was assumed to rotate on its axis.[10]

But the eleventh century mathematician and physicist Ibn Haitham had raised objections on the equant hypothesis of Ptolemaic planetary theory. He concluded that the arrangements proposed for planetary motion in the *Almagest* were false and that the true arrangements were yet to be discovered. This criticism played an important part in stimulating research at thirteenth century Maragha that led to the construction of a non-Ptolemaic model, the purpose of which was to preserve the uniformity principle without sacrificing the mathematical effect of the equant.[11]

Another great astronomer of Maragha of the thirteenth century, Qutab Al-Din Al-Shirazi (1236-1311), who played a major role in the observations made in Maragha, which led to the composition of the *Ilkhani Zij* of Nasir Al-Din Al-Tusi, emphasized the relation between the movements of the Sun and the planets, which prepared the way for Copernicus. In fact, according to Kennedy, the new planetary model came out of Maragha which represented the most important departure from the Ptolemaic model in medieval times and was essentially the same as that of Copernicus, provided one ignored the heliostatic hypothesis.[12] The planetary model which Qutab Al-Din used for all the planets except Mercury could be summarized as given in figure 3.

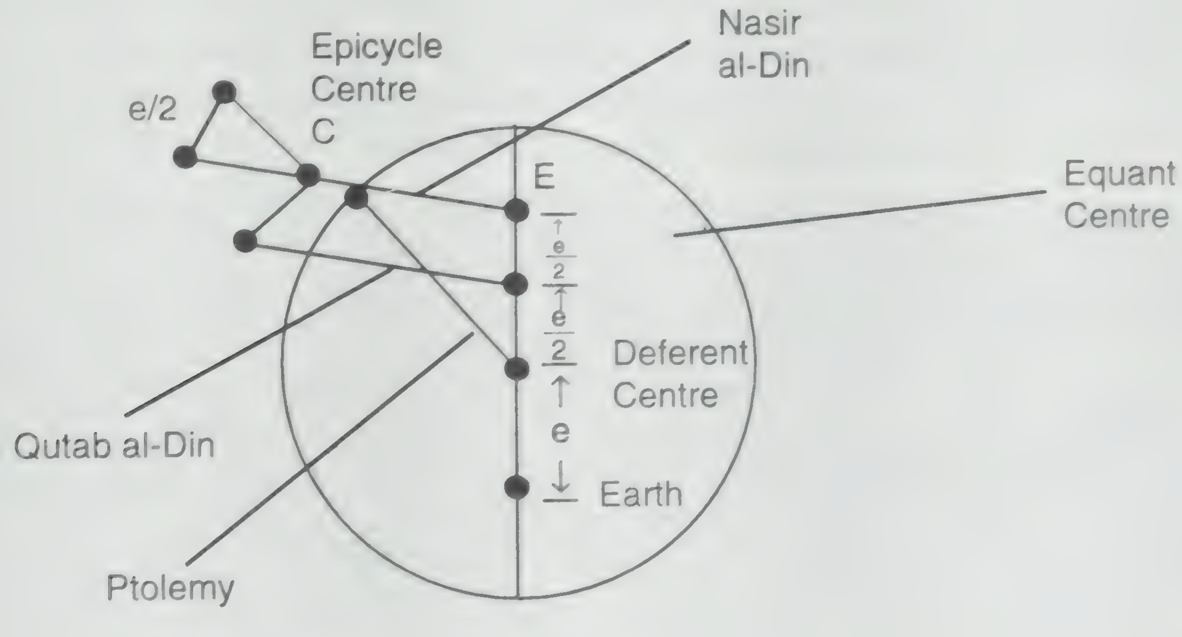


Fig. 3

It would not be out of place to mention that *Zij Ilkhani* played an important role in interacting with the Indian astronomers of medieval period. Mulla Mahmud Jaunpuri (b. 1606), and Indian theoretical astronomer and philosopher, also raised objections regarding the validity of Ptolemaic planetary hypothesis. In his *Shams-i-Bazegha*, Mulla Mahmud expressed his views as follows:[13]

> Though the number of spheres proposed by Ptolemy may suffice for resolving the anomalies with regard to acceleration and retardation, but the following problem still remains unsolved: Normally how is it that the centres of epicycles in the case of planets (other than the Moon) revolving around the centre of an imaginary sphere called

> Equant with uniform velocity, and in the case of the Moon, round the centre of the universe, and how is it that they did not revolve with uniform velocity round the centre of their deferents as is evident from the fundamental principles. For this reason, later astronomers have increased the number of component spheres, but hold conflicting views regarding their demonstrations.

Copernico-Kepler-model

The concept of Ptolemy's geocentric Universe was acceptable for about 1400 years to astronomical scientists. But it was Nicholas Copernicus, born in 1473, who attempted to restore ancient physics by constructing a model of the solar system which would fit the observations of planetary motions available to him. His mind was wedded to the ancient ideal of circular motions, and in the words of Kepler in the seventeenth century, Copernicus tried to interpret Ptolemy rather than nature. Copernicus believed that the perfect motion was only in a circle, 'because it has a cause that does not slacken'. He observed that planetary motions seemed different at times, but he thought the irregularities could all be explained. Perhaps the motions only seemed unequal because the planets were located at different distances.[14]

In the Copernican system the Sun stood still at or near the centre of the Universe and the Earth moved around it in circular orbit and, further in his view, circular motion was always uniform.

In Ptolemaic planetary theory, the planets moved on the epicycle in the same direction as the epicycle moved on the deferent, whereas in Copernican theory the Earth and the planets moved about the Sun in the same direction and not in the opposite direction.[15]

It is important to note that the Copernican theory of planetary motion was not totally independent from Ptolemaic. Copernicus rendered Ptolemaic theory in the new context using the same astronomical apparatus and techniques. Joseph[16] explained this as follows:

> ... for exactly as in the geostatic and heliokinetic cosmology by Ptolemy, the tables which accompany the heliostatic and geokinetic system of Copernicus yield geocentric planetary positions directly and from a single procedure. Hence, as equally representative specimens of positional astronomy, the basic techniques of both Ptolemy and Copernicus are observationally equivalent to the naked eye and empirically indistinguishable. Nor is such mimetic parallelism effectively diminished by the circular metamorphosis through which Copernicus tries to contrive such a combination of (a) eccentric circle and one epicycle or (b) concentric circle and two epicycles with reference to his own mean sun, as will be geometrically equivalent to Ptolemy's more candid combination of eccentric and equant circle with respect to the earth.

Three years after the death of Copernicus was born Tycho Brahe (1546-1601), a great experimentalist who devised new and accurate instruments like the quadrant and the sextant. His measurements were accurate and he did not accept the Copernican system. He concluded that Copernicus' assumption that the Earth moved in space defied the scriptures and violated the principles of physics and so he set out to rehabilitate Ptolemaic astronomy. Brahe succeeded in stating Ptolemy's system by showing that the Sun revolved around the Earth and the planets turned around the Sun in epicycles.[17]

The most modern astronomer of the medieval period, Johannes Kepler (1571-1630), a convinced follower of Copernicus who had himself said, 'What a wonderful thing it would be if I could prove Copernicus' theory', became an assistant of Brahe. Kepler took over Brahe's records and tried to prove the truth of the Copernican heliocentric model with Brahe's observations. But he never found circular orbits and even any of the explanations suggested by Copernicus. Thus the question arose: 'Was planetary motion really non-uniform?' Finally he put the Sun in an off-centre position and drew lines considering points on the circumference of the circle for equal time. He found that nearer the Sun the arcs were longer which meant that the planet was covering more distance in the set time. The arc farthest away from the Sun was the shortest, showing that the planet covered very little distance in the same length of time. Finally he reached the conclusion that the shape of the planetary orbit was elliptical. But for most planets (Mercury being an exception) the ellipses were not very different in shape from a true circle, but the sun was not at or even near the centre; the situation was very much like a circular orbit (or quasi-circular elliptical orbit) in which the Sun was notably off-centre. From this hypothesis Kepler established three laws of planetary motion. Amongst them, one stated, 'The orbit of every planet in an ellipse has the sun at one focus.'

Jai Singh-Khair Allah-Ghulam Hussain Model

Jai Singh (1688-1743) was a great astronomer of medieval India. His knowledge of astronomy was based not only on Indian astronomical texts but also on Arabic and Persian. He got the *Tahrir al-Majesti* of Nasir Al-Din Al-Tusi, translated into Sanskrit as *Samrat-siddhanta* by his associate Jagannatha Samrat, and *Zij-i-Ulugh Begi* as *Tarasarani* by his Jyotisa Rai Kewal Ram. But it seemed he was not interested in the translation of Copernicus' book *Revolutionibus* or rather there was no influence of contemporary European astronomy on him. He prepared *Zij-i-Muhammad Shahi* mainly based on *Zij-i-Ulugh Begi* and dedicated it to Emperor Muhammad Shah (reign 1719-48).

It may be noted here that Jai Singh's reception of European astronomy was not confined to just the use of the telescope, but he also accepted the European emphasis on observations. Consequently, he matched the observations (Marsud) with theory (Mahsub) in contrast to his predecessors.[18] However, Jai Singh preferred Ptolemaic geocentric model of planetary motion, instead of the heliocentric model of Copernicus and thus became the last link in the tradition of Nasir Al-Din Al-Tusi and Ulugh Beg.

It would not be out of place to mention that if discrepancies were noted between the predicted results and the observations, it were the measurements of observations that he suspected and not the theoretical basis of the predictions. In fact there was no evidence to suggest that Jai Singh ever doubted the geocentric system of Ptolemy.[19]

But the question arises as to why did Jai Singh not use the heliocentric system for observation of planetary motions although charts on the planetary system of Copernicus and Tycho Brahe were available to him.[20] Perhaps the Copernican hypothesis of planetary motion was not very popular amongst astronomers, and Jai Singh could not appreciate it. This might have been because the introduction of the heliocentric world picture would not lead to greater accuracy of the planetary table, as Dijksterhuis pointed out. It was therefore not surprising that no textbook widely used in Europe in the sixteenth century expounded the Copernican theory and few even mentioned it.[21]

An eighteenth century astronomer and mathematician Khair Allah Khan, an associate of Jai Singh, also asserted ellipticity of all orbits in his *Sharh-i-Zij-e-Muhammad Shahi*. The details of this were found in *Jame Bahadur Khani* of Ghulam Hussain Jaunpuri. According to him, the majority of the ancient and most of the modern observers found the orbit to be an eccentric circle, and derived the partial equation on this hypothesis, yet not only the orbit of the Sun was eccentric, the orbits of all other planets were of an elliptical form. As proof, if we calculate the positions of the Sun and the planets according to the equation of a circle we do not find them agreeable to observations. On the contrary to what takes place in the equation which is produced in the case of the ellipses, if we determine these positions from that latter calculation, these would be more agreeable to observation. Hence, it proves that the orbits are elliptical.[22]

Ghulam Hussain explained his hypothesis as follows.[23]

> This supposition (the orbits are elliptical) is realized by supposing the existence of two spheres (aflak) one agreeable (muhassil), the other eccentric (kharij-al-markaz), so that the distance between the two centres should be equal to half the distance between the known centres and the circumference of the eccentric sphere, an epicycle (kharij al-markaz al-tadwir) whose semi-diameter is equal to half the difference of the two diameters, the major and minor of the ellipse (baizawi), that is in the figure of the solid sphere, the semi-diameter of the sun, and the superior movement of the epicycle is to be in the same direction as that of the eccentric sphere, and of double the angular velocity and in the beginning of things the centre of the epicycle must have been at the greatest distance of the eccentric sphere, and the centre of the sun at the greatest distance of the epicycle. In this case, by the motion of the epicycle and the eccentric sphere, the centre of the sun will describe an orbit similar to an elliptic orbit and the centre of the universe will be one of the two focal points of the ellipse, and the centre of the eccentric sphere will fall in the place of the centre of the ellipse and the other focal point, towards the other side of the eccentric sphere, in the direction of the apogee (auj al-aflak), at the same distance as is between the centre of the universe and the centre of the eccentric sphere, and the distance between the two focal points is called the sine of the extreme equation, and the second focal point is supposed to be the known place of the eccentricity, so that the epicycle should be carried out of the middle, and all that has been said will be evident from this figure (Fig. 4).

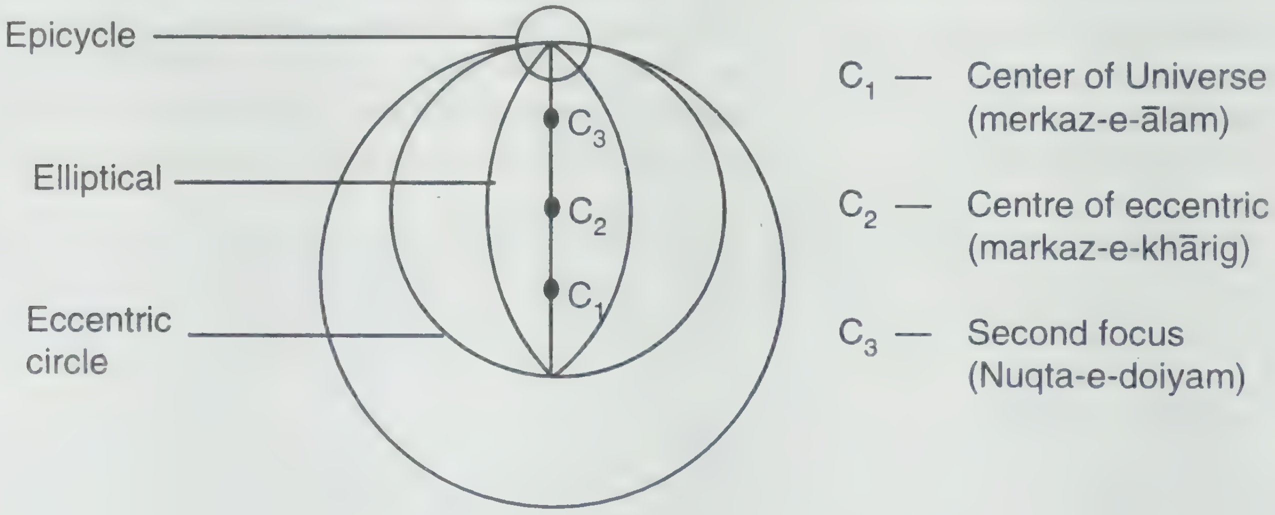

Epicycle
Elliptical
Eccentric circle
C3
C2
C1
C1 — Center of Universe (merkaz-e-ālam)
C2 — Centre of eccentric (markaz-e-khārig)
C3 — Second focus (Nuqta-e-doiyam)

Fig. 4

Ghulam Hussain remarked, that this demonstration would not prove the orbit to be exactly elliptical, but only that from the small space between the two focal points, it was very similar to an ellipse, and the equation which was obtained on the supposition of an ellipse was not perceptibly different.[24]

Ghulam Hussain explained the method of finding the equation of an elliptical orbit as follows:[25]

Let ABCD be an elliptical orbit (madar-e-baizawi), with AC its major (qutr-e-atwal) and BED its minor diameter (qutr-e-aqsar) intersecting at right angle (Fig. 5). H is the centre of the Universe (alam) which is one of the two focal points. G is the place of eccentricity, which is the second focal point. A is the sun's point of apogee (auj). C is the point of perigee (hadid), and we suppose T, on the circumference of the ellipse, to be the centre of the Sun. Join GT and HT to get the angle AGT, which is the measure of the motion of the Sun's centre from the point A. Similarly, you get the angle TGH, which is the complement of the angle AGT to the half circumference. The two sides GT and HT, though they are not known separately, yet their sum which is equal to AC, the major diameter of the ellipse (i.e. 120°), is known. Produce GT towards I till GI is equal to the major distance. Hence, it is necessary that TI is equal to HT. Join IH to produce the isosceles triangle HTI. Now we say that in the triangle HGI two sides HG and GI and the angle HGI are known. Hence, the remaining sides and angle can be obtained. Therefore, the side IH and the two angles GHI and GIH are known. Since the two angles THI and TIH on account of equality of TI and TH are equal to the exterior angle GTH of the triangle HGT, the angle of the equation is known to be double of the angle TIH.

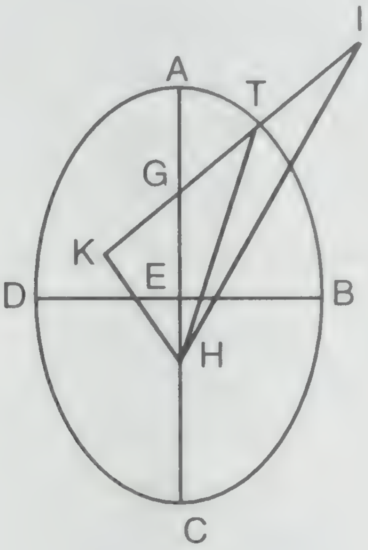


Fig. 5

Draw a perpendicular HK from the point H to IG. Since in the right-angled triangle, HKG.

GH = 2° 0' 37" 24'''
and let ∠AGT = 60°
so ∠KGH = 60° an opposite angle
and ∠K = 90°
hence ∠GHK = 30°
Therefore, HK = GH sin (HGK)
= 1° 44' 27" 25''', where sine (HGK) = 51' 57" 41'''
Similarly, GK = GH sin (GHK)
= 1° 0' 18" 42''', where sine (GHK) = 30°

Now, in the right-angled triangle, IKH,
IK = 121° 0' 18" 42'''
and sq, IK = 4.4.2° 16' 36"61'''
and sq, HK = 3° 1' 11" 15''' 12^{iv}
hence sq IK + sq, HK = 4.4.5° 17' 49" 18''' 13^{iv}
so, IH = 121° 1' 1" 3'''
and sin (I) = HK/HI = 0.51° 47' 22"

and the arc of this in the table of sines is the magnitude of the angle of the equation GHT, 1° 38' 54". Here one observes that the extreme excess of the annual equations of the point of the greatest and least distance is 0° 1' 58". If this difference be added to the mean daily (motion) of the Sun, the sum (i.e. 1° 1' 6" 20''') is the greatest daily velocity of the Sun. And if it is subtracted from the mean daily motion, then the remainder (i.e. 0° 57' 10" 20''') is the least daily velocity.

Thus, Ghulam Hussain concluded that European philosophers considered the Earth as moving in an elliptical orbit, and the Sun as fixed in the major diameter of the ellipse, so that the centre of the Sun coincided with one of the two focal points, and the centre of the ecliptic itself became the centre of the Sun.

For example in Fig.6, ABCD is the elliptic orbit of the motion of Earth and AC is the major diameter, and the two focal points on the major diameter are E and AG, and HT is the Sun's disc (jirm-i-shams) and IKLM is the ecliptic (mintaqul-buruj). Then, after determining these lines, Ghulam Hussain says that if the Earth passes over the point C, it is at its least distance from the Sun, and with respect to the ecliptic it is at the point L. It is supposed that the place of the Sun is at the point I, which is its higher apsis and is opposite to the point L. Thus the position of the Earth at every point being known, the position of the Sun is to be considered as opposite to that. And if the Earth proceeds from the point C towards D it is supposed that the Sun proceeds from I towards K, and the distance of the Earth from the Sun increases daily, till it comes to the point A, and then the Earth will have come to its greatest distance from the sun, and the sun is seen at the point L, and this point L is imagined to be the higher apsis of the sun. The distance of its passage from the point A is the decremental distance, and when it reaches C, then it appears in its original state. As BCD is less than half of the elliptic orbit, and the part corresponding to it in the ecliptic is a semicircle, so an inhabitant of the Earth passes over this half quickly. And hence he supposes that the sun passes through the half MIK quickly, and for the same reason the Earth passes over the half KIM. It is certain that from the Earth the situation of the Sun appears opposite to that of the Earth. So he (the spectator) is supposed to be looking at the centre of the Sun, the place of the Earth will appear opposite to the Sun, i.e. in that half in which the motion of the Sun appears slow and the Earth will appear to go quick, and in the quick half slow. Hence, if the equation which has been found by the demonstration with reference to the focal point be brought into operation reversely on the supposition of the Earth's motion, and the place of the Earth be determined, will be found. It is sufficient for us, if after determining the Sun's place to add or subtract half a revolution to or from it, so that according to the phraseology of Europeans, we may obtain the Earth's place.[26]

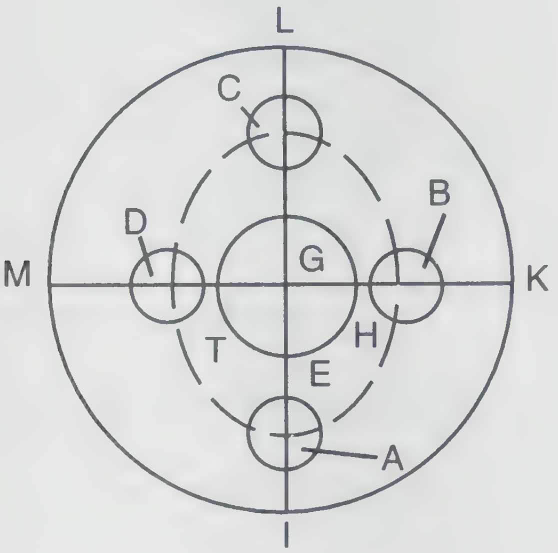


Fig. 6

Thus we could conclude that the Copernicus-Kepler's model of planetary motion could get acceptance in India, after verification in the later part of medieval times through Khair Allah Muhandis.

III. ZIJES AND ASTRONOMICAL OBSERVATORIES

Arabic-Persian Zijes During Medieval Times

Late antiquity, Byzantine and Islam upheld theoretical astronomy on an intelligible level, even improving important mathematical and some astronomical details.[1] Bait al-Hikma (House of Wisdom) was established at Baghdad in the reign of Al-Mamum (813-633) and many astronomers of repute from various regions, like Syria, Iran and Mesopotamia were associated with this centre. Two most important zijes were prepared at this centre, one by Al-Khwarizmi and the other by Yahya Abi Mansur. Al-Khwarizmi's zij contained purely Ptolemaean methods and parameters, while Yahya Abi Mansur's zij included both Indo-Iranian and pre-Ptolemaen Greek methods.[2] Al-Khwarizmi's zij did not contain the results of his own observations. It was considered as a theoretical guide and formed the foundation of astronomy in the epoch of Renaissance.

But during medieval period two most important zijes were prepared in Arabic and Persian based on observations, which greatly influenced the not only Arab and Iranian astronomers but also those of India and Europe until the eighteenth century. The first was the *Zij-i-Ilkhani* of Nasir al-Din Al-Tusi. This zij was based on the observations made at the Maragha observatory during 1265-81, which served as a model for subsequent zijes. The Maragha observatory was built near Tabraj by Halaku Khan, the Ilkhani ruler of Iran, on the advice of and under the directorship of Nasir al-Din Al-Tusi in 1258.

In the latter half of the fourteenth century the centre of scientific activities shifted to central Asia, and the last important Islamic observatory was founded in 1420 by Timur's grandson Ulugh Beg (1393-1449) in Samarqand. A group of prominent scholars, among them Al-Kashi (d. 1429), was entrusted with the planning and development of this observatory. The other important astronomers who were associated with this observatory were Qadizada Rumi and Ata al-Din Qaushji. The findings of the observatory were compiled by the king with the help of Qaushji in what was subsequently called *Zij-i-Ulugh Beg*[3] in 1438, and this zij remained for a long time the most important source of astronomical computation. It was also called *Zij-i-Jadid-i Gurkani*. This zij could be put in the category of *Zij-i-Rasadi* (i.e. observational tables).

It may be mentioned here that no zij seemed to have been prepared after Ulugh Beg's zij in Iran or central Asia. Some zijes were prepared in west Asia, but they did not influence the zij literature of India.[4]

Zijes Compiled in India during Medieval Times

During the medieval period two types of zijes were prepared in India: (i) *Zij-i-Hisabi* (computational tables), and (ii) *Zij-i-Radadi* (observational tables) and most of them were based on *Zij-i-Ilkhani* and *Zij-i-Ulugh Beg*.

The first zij prepared in India was *Zij-i-Nasiri* by Muhammad bin Umar during the reign of Sultan Nasir al-Din-Muhammad bin Shams al-Din Iltutamish (1246-65), to whom it was dedicated. Unfortunately this zij is not extant anywhere.

A Sanskrit translation of *Zij-i-Ulugh Beg* was prepared by Fathullah Shirazi, by the order of Emperor Akbar, with the help of Abul Fadl.[5] A court astronomer Mulla Chand also made *Tashil Zij-i-Ulugh Beg* (a simplified version). In *Tashil*, Mulla Chand made some alterations in the arrangement of the original zij and he deleted the first maqala dealing with Chinese and Uighur calendar.[6]

The next important zij was *Zij-i-Shah Jahani* compiled by a scholar astronomer Mulla Farid in the second year of Shah Jahan's reign. This zij was based on Ulugh Beg's zij which was the most reliable and most correct of all the zijes available at that time. Mulla Farid did not go for fresh observations to prepare this zij but he updated and improved the tables in comparison with Ulugh Beg's zij.

The court chronicler Muhammad Saleh Kamboh spoke very highly of this zij, which in his own words, pushed into oblivion and disuse even *Zij-i-Ulugh Beg*on which it was based. The Emperor Shah Jahan was so much impressed by its utility that he ordered it to be translated into Sanskrit for the use of the general public.

However, the importance of this zij lies in the fact that it was studied by Sawai Jai Singh also in the eighteenth century before he undertook preparation of his own *Zij-i-Muhammad Shahi.*[8]

One of the last major endeavours in astronomy, in the tradition of medieval astronomers of Asia, was undertaken by Sawai Jai Singh in the early eighteenth century. Sawai Jai Singh was a great scholar of his time in mathematics and especially astronomy. He studied astronomical tables, not only those based on Siddhantic Jyotisa but also those of Arabic and modern European astronomy. Jai Singh observed that the astronomical tables of his times had become outdated. He found that the calculations of star-positions according to the tables in common use varied widely with the observation. Particularly, appearance of the new Moon did not agree with its predictions.[10] This matter was brought before Emperor Muhammad Shah who ordered him to construct observatories based on different systems of astronomy. Thereupon, Jai Singh prepared a programme to revive astronomy in India. He built observatories in Delhi, Jaipur, Mathura, Ujjain and Banaras, which were identical in design with the one in Samarqand; and on the basis of long standing observations taken from these observatories he compiled astronomical tables entitled *Zij-i-Muhammad Shahi* based on Ulugh Beg's zij in Persian.[11] It was completed in 1728. There was one copy at least of the text prepared in Devanagari, a reference to which exists in the Jaipur archives.[12]

It may be noted here that in these observatories, Jai Singh used advanced and accurate instruments and therefore the results computed on the basis of observations taken were found more accurate than Ulugh Beg's observations, which were taken 300 years ago.

The zij was divided into three chapters. The first dealt with various calendars—the Hijri, Muhammad Shahi, Samvat and Christian era—and conversion from one era to another. The second chapter was divided into 19 sections dealing with practical astronomy and spherical trigonometry, determination of coordinates of heavenly bodies, methods for determination of the meridian latitude and longitude and measurement of distances between planets and stars, etc. The third chapter was devoted to planetary motions and positions.

It will not be out of place to mention that a commentary on the zij was written later by an associate of Sawai Jai Singh, Khair Allah Khan bin Lutf Allah Muhandis Lahauri, an advisor on the building of observatories. In this commentary entitled *Sharh-i-Zij-i-Muhammad-Shahi* Khair Allah Khan stated that, whenever the different positions of the Sun and other planets were calculated in accordance with equations of the circle, they did not conform to what was actually observed. On the other hand, when the equations were derived by taking the orbits as elliptical and calculating the positions calculations generally agreed with the observations made. Hence he concluded the orbits to be elliptical.[13]

It should be noted that this remark was based on observations only; and there was no evidence that Khair Allah Khan had any knowledge of Kepler's theory of planetary motion.

A well-written compendium of mathematical sciences entitled *Jame Bahadur Khani* (1835), was composed by an early nineteenth century mathematician and astronomer, Ghulam Hussain Jaunpuri (1790-1832). The author worked as the chief justice (qazi al-quzzat) at the princely state of Raja Bahadur Khan of Tikari. Afterwards, he served the Raja of Banaras and he was asked to repair the observatory of Banaras, but due to the huge funds required the job could not be undertaken.

The *Jame Bahadur Khani* might be called as an encyclopaedia of mathematical sciences. It dealt with geometry, spherical trigonometry and optics, but the main emphasis was on astronomy and preparation of zijes and calendars. In chapter five, the author discussed in detail the basic principles of astronomy, the astronomical instruments and their use, rules of observation, and determination of means and equable motion, latitude and longitude of planets and stars. There were a number of astronomical tables apart from a revised star catalogue.

After completion of *Jame Bahadur Khani,* Ghulam Hussain Jaunpuri felt that constant revision of astronomical tables based on fresh observations were necessary. Therefore, he submitted this proposal to his patron Raja Khan Bahadur for execution, wherein he stated:[14]

> That the result (in *Jame Bahadur Khani*) is the compilation of a fresh set of astronomical tables, which is in need of constant revision and reform in all successive periods of time, and this must be based on fresh astronomical observations.... Moreover, recently European scholars have designed and manufactured highly sophisticated and fine astronomical instruments, which have made astronomical observations independent of big and clumsy instruments used by Greco-Arabic astronomy If observations of stars are made for some years, the difference between the observed times and that which is computed with the help of *Zij-i-Muhammad Shahi* will be eliminated...I have been observing and keeping a proper record of these observations and this will also help in the preparation of the new tables.

Thus, Ghulam Hussain utilized his expertise in the subject and made fresh observations of the motion of stars and planets and did find their longitudes and latitudes, relative positions, conjunctions etc., and put them in a new zij entitled *Zij-i-Bahadur Khani.*

Astronomical Instruments in Medieval India

The astronomical instruments had been developing since the early Vedanga Jyotisa up to the medieval period. The 'shadow of gnomon' (vertical staff) was the first device used by man in ancient times for finding time, seasons and some other astronomical constants. But over a long period of time more astronomical instruments were developed. Bhaskara-II described ten astronomical instruments—namely, golanadivalaya, yasti, sanku, ghati, cakra, capa, turya, phalaka and dhi—in the Yantraadhyaya of his *Siddantasiromani.* Among them, the first eight instruments were common with the previous siddhantas of Brahmagupta, Lalla and Sripati.[15]

During medieval times several treatises on astronomical instruments were composed in Sanskrit. Mahendra Suri (1320) composted *Yantraraja,* possibly the first text of this kind, dealing with the preparation of astronomical instruments by means of which the time of day and night could be accurately ascertained. There were two commentaries on it—one was *Yantrarajatika* by Malayendu (*c.* 1659) and another was by Mathuranatha Sukla (1758).

With the passage of time, a sixteenth century astronomer Ganesha Daivajna (b. 1507) independently developed an astronomical instrument called Pratoda Yantra—a cylindrical sundial with a horizontal gnomon and different graduations for every month. With the help of this yantra one could measure time very easily. Ganesha described the details of construction of this yantra and its use in 13 verses[16] in his monograph *Pratoda yantra.*

The Pratoda yantra, which meant chabuka or whip instrument, was so named because of its shape (Fig.7). It was made out of a wooden rod which was neither too thick nor too thin in radius. It was usually 10-20 'angulas' in length and about 3 'angulas' in diameter. It was made uniform and was lined lengthwise with grooves with the help of some sharp device.

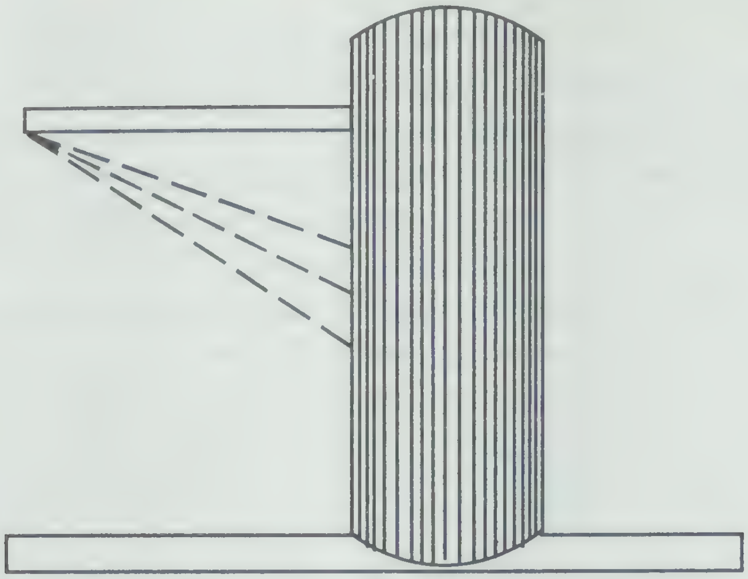


Fig. 7

If the vertical gnomon is compared with this yantra, the Shanku and Drigiya are found to be interchangeable and the horizontal gnomon shadow is zero at transit while it is infinite with the vertical gnomon, and reverse is the case at the time of sunrise.

Before taking up the task of construction of observatories, Jai Singh was greatly fascinated with Greco-Arabic metallic astronomical instruments. He even modified these instruments according to his requirements. But later on he realized that these instruments, although very handy, suffered from serious limitations on account of their small size and, therefore, the calculation and observations were somewhat inaccurate, because the atmospheric conditions had a strong influence on those instruments. This was particularly indicated by accuracy of the observation and measurements made by Hipparchus, Ptolemy and others.[17] Therefore, to obtain quite accurate measurements, Jai Singh preferred to construct huge masonry instruments and in this connection, he said:[18]

> These instruments were made of metal and stone. It should be mentioned that these instruments were based on laws of geometry, and atmospheric conditions were also taken into account. These instruments were very very large and accurate. With the help of these instruments we determined time, the movement of planets and their visibility more accurately. Thus by the same instruments we removed the defects in the preceding astronomical tables as far as possible'.

However, Jai Singh developed three new astronomical instruments to remove the defects of earlier instruments, as was mentioned in the preface of *Zij-i-Muhammad Shahi*. These instruments were: Samrat Jantar (Yantra), Jai Prakash and Ram Jantar. There were some other instruments also in his observatories, but they were not invented by him. These yantras were made of lime and stone of perfect stability and adjusted to meridians and latitudes of the place. It should be noted that these instruments were common in Delhi and Jaipur observatories.

Brief descriptions of the instruments designed by Jai Sigh are given below:

Samrat Yantra: This instrument is an equinoctial sundial wherein triangular gnomon in the form of sundial with slanting styles is an important part (Fig. 8). And on the slanting side parallel to the axis of the Earth, on either sides of the gnomon, there are two quadrants of a circle parallel to the plane of the equator, and its centre lies on the slant side of gnomon. The surface of the quadrants is graduated into time measuring units.

Jai Singh built Samrat Yantra in several sizes.[19] This instrument was used for finding the apparent solar time of a place.

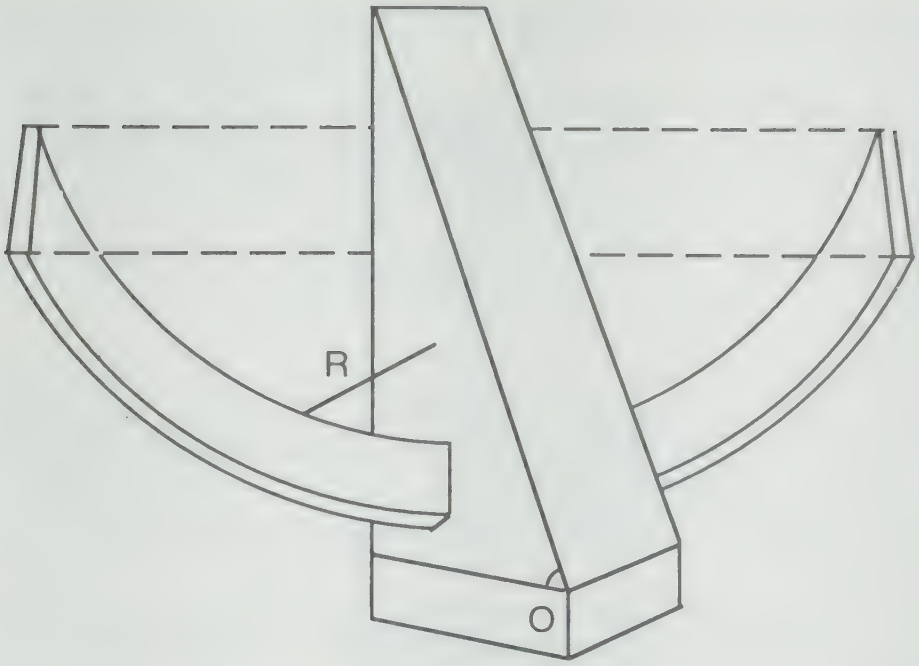


Fig. 8

Jai Prakash: The Jai Prakash yantra was called the crest jewel or yantra siromani by Jagannatha Samrat. It is an armillary sphere cut into two by the plane of the horizon, only the upper surface being kept visible to us (Fig.9). It consists of a concave hemisphere dug in the ground. The rim represents the horizon of the place of observation and is graduated in degrees and minutes.[20] Cardinal points are marked on the horizon and cross-wires stretched between them.

This instrument was used to determine the position of the Sun, which was obtained from the shadow of the cross-wires falling on the concave surface.

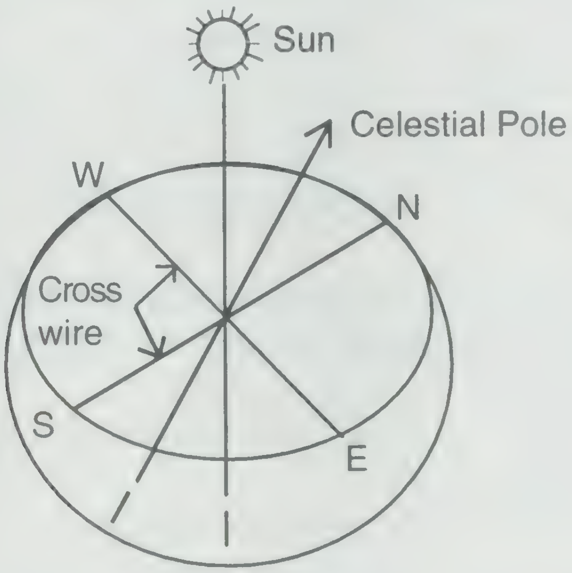


Fig. 9

Ram Yantra: This instrument comprises a cylindrical pillar at the centre and outer walls of the same height (Fig.10). It was used for measuring the altitude and azimuth of the sun. The interior walls and of the structure are engraved with scales for measuring the angle.

The Use of Telescope

It is not known that Jai Singh ever used the telescope for observational purposes along with his instruments, although it was available to him as he himself expressed in *Zij-i-Muhammad Shahi.*[21]

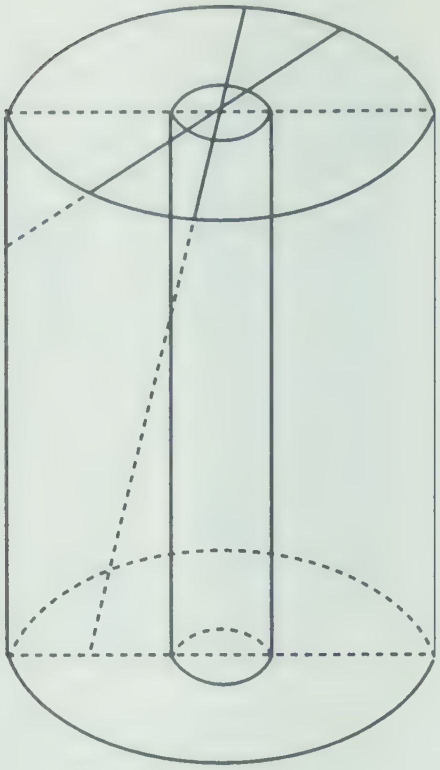


Fig. 10

With the telescope man made many discoveries contrary to the well-known assertions given in the ancient texts. For instance, it helped us see with our own eyes that Mercury and Venus got their light from the Sun as did the Moon.

However, as Sharma concluded,[22] 'Although telescope is discussed in some detail in the *Zij-i-Muhammad Shahi...* it does not have any telescopic data such as tables on the satellites of Jupiter or on the phases of Venus. Further there is no evidence within the zij to suggest that its author was familiar with the theoretical developments by Kepler or Newton'. In fact, Jai Singh's researches were primarily confined to the instruments of the medieval period.

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CHAPTER VIII

Indian Food Concepts

K.T. Achaya

I. FOOD AND THE INDIAN ETHOS

The *Bhagavad-Gita* states: 'From food do all creatures come into being.' All living creatures, we read elsewhere, pursue food, and the body is the product of the food that is eaten. The *Taittiriya Upanishad* states: "From earth sprang herbs, from herbs food, from food seed, from seed man. Man thus consists of the essence of food... From food are all creatures produced, by food do they grow... The self consists of food, of breath, of mind, of understanding, of bliss." The unifying cosmic Aryan cycle envisaged that the eater of food, the food that he eats, and the universe must all be in harmony. It is from such sweeping concepts of what food is and should be that spring a unique set of beliefs and practices.

Kaccha and Pucca Foods

The Kanyakubja in Uttar Pradesh are an ancient people. They were already 2000 years old when visited in the seventh century AD by the Chinese pilgrim Xuan Zang. Ancient ritual usages are still preserved by these orthodox Brahmans, such as the distinctions between Kaccha and Pucca foods. Though, literally, Kaccha means partly-done or imperfect, and Pucca the opposite, the terms have a different connotation in ritual practices. Kaccha foods are those prepared and eaten afresh at every meal, like boiled rice, Dhal and Roti. Elaborate ritual rules have to be followed in their preparation, to make the products exclusive and pure. Generally, the cooking of all cereals and most pulses is intrinsically pure, and such cooking must also be conducted in a ritual cooking pot, the Sthali. Boiling milk also yields a Kaccha food. If the cook is a family member, or a Brahman employee, he must have a bath and don fresh, hand-washed clothes before entering the kitchen. A stitched upper garment, such a Jibba, is considered polluting, and must be removed before cooking. Once the cooking starts, the cook will have to remain in the kitchen till the food has been cooked, served and eaten following ritual rules. Should he leave the kitchen, another bath, fresh clothes and cooking anew will be mandatory. Kaccha food can be plain or festive, cheap or expensive, nutritionally simple or complex; what makes it Kaccha is its cooking in a pot following ritual rules.

Pucca foods are essentially those cooked using a fat that is morally superior, namely Ghee. Such foods after cooking can be used outside the domestic cooking area, and can be shared by those of either higher or lower levels of purity. Pucca cooking activity is inclusive, and has fewer ritual regulations than those governing Kaccha cooking. While deep or shallow frying is what may be required, it is the sequence of contact of water, fire, Ghee and salt, in ritual terms of touch, that will determine whether the resulting food is Pucca or Kaccha. A Pucca kheer will result if rice is first brought into contact with Ghee before it is placed on the fire, and milk and sugar are then added; the same four ingredients, should the order of contact be different, will yield a restrictive, Kaccha, Doodh-bath. If, in making a Parata Ghee is first added to the pan and only thereafter the rolled-out dough, a Pucca food will result. A Halwa for communal sharing must likewise be made in this way. The distinction particularly affects food materials most employed in cooking, like rice, wheat, Thuvar Dhal and Urad Dhal.

The Cooking Ethos

The domestic hearth in an Indian home was regarded as an area of high purity, even of sanctity. Frequently, it was erected next to the area of worship, demarcated from sitting, sleeping and visitor-receiving areas, and particularly well away from areas of all types of waste-disposal. Pure and impure areas could not face each other. The hearth was set up conforming to these compulsions on some auspicious forenoon of a bright fortnight during Uttarayana, the northern course of the Sun.

The purpose of cooking was not just to produce materials that could be eaten. It was to conjoin the cultural properties of the food with those of the eater by the use of methods that were both ritually pure and auspicious. The act of cooking involved five elements, namely, fire, water, Ghee, Anna or cultivated grains, and Phala or uncultivated food materials. Milk and Ghee had a special significance in that they were considered as being already fully cooked in a ritual sense, and thus culturally neutral, unlike food materials that were altered by fire. The two major divisions of cooking were (a) cooking without the use of fire and (b) cooking with fire. Cooking without fire had three sub-classes. One was the use of water, for example to wash vegetables in the kitchen to render them ritually pure prior to peeling, cutting, sifting or grinding. The second concerned the use of milk and milk products like curd or buttermilk, in the cold. Three highly auspicious products were made simply by mixing: Madhuparka, a mix of Ghee, curd, milk, honey and sugar; Panchagavya, a melange of five products of the cow; and Panchamritha, a blend of five fruits or fruit juices with honey and sugar. The third sub-division of cooking without fire, viz. that of cooking with air and sun, involved sun-drying of fruits and vegetables for their preservation, or the pickling of vegetables and semi-ripe fruits using oil and spices.

Cooking with fire, involving application of heat, had two broad categories. These, in general, corresponded with Kaccha foods in which Ghee was not used, and Pucca foods in which it was. Ghee-cooked foods could employ cultivated grains or Anna, either with or without water and/or salt; they could also use food materials classed as Phalahar, like vegetables, fruit, milk and milk-products. This latter category would cover shallow-fried vegetables, whereas boiling or stewing would comprise cooking on a fire without Ghee.

Ritual classifications apart, from very early times seven types of cooking were recognized: Talanam or drying; Pachanam or cooking in water; Svedanam or steaming; Kvathanam or parboiling; Bharjanam or dry roasting; Tanduram or grilling; and Putapaka or baking. These operations were conducted, and food served, using an impressive range of utensils and implements.

Pollution and Spoilage

Actual cooking and eating were pervaded by concepts of ritual pollution, which carried strong elements of hygiene and cleanliness. Saliva was regarded as highly polluting: water from a tumbler could not therefore be sipped, for fear of contamination with one's own saliva; it was to be poured into the mouth from above using the left hand. Water used for rinsing the mouth could not be swallowed, but had to be spat out. Water had a strong association with purification, and was used for sprinkling in many contexts: on the leaf before eating, in a temple ritual, at a marriage, or during a penance. A bath was to be taken only in moving water—as in a flowing river or stream, or by laving it over oneself from a bucket—never in still water. Cross-pollution was guarded against by eating off disposable materials like Palas leaves stitched together with slivers of hay or cane, or large leaves like those of lotus or banana; and by using leaf-fashioned or clay cups for drinking soups, fruit juices or milk confections.

Kaccha everyday food, which was essentially boiled food, had to be cooked afresh for each meal. Excess left-over food was termed Bhrasht (Basi) or Dushith (Jootha); it was not to be used again and was discarded as being polluted.

Pollution concepts were linked with caste. Food could be exchanged between equals, given to lower castes and received from higher ones. A Brahman could give cooked food to any other caste, but a higher caste could on no account receive food from a lower one. Patanjali remarked that while food vessels used by carpenters, blacksmiths, washermen and weavers, all of low caste, could be used by others after certain rigorous and carefully-specified methods of cleansing, no known method was adequate to purify the food vessels used by untouchable castes like the Chandalas and Mritapas. Low castes could not even live within the city limits for fear of polluting others, and perforce stayed outside them.

II. FOOD AND THE LIFE CYCLE

A Brahman Grhastha (householder) followed a strict ritual in taking his meal. He would be the first to enter the eating area after having had a bath, changed into washed-and-dried clothes and offered his prayers, to take his place closest to the cooking area. The higher the status of the eater, the less polluted were his food residues considered to be; were a lower ranked person to eat first, the entire food area and the rest of the food would be considered contaminated. Food could only be eaten sitting down—not when standing or lying down; it had to be done alone and in total silence (Maun).

Ritual Oblations

Everything had to be in order: proper time, proper space, proper vessels. The cook should already have offered the food to god. The eater of the meal should also have already made sure that all his dependents like aged persons, pregnant women, infants and any guests had been fed. Morsels of the food were first cast into the fire as a sacrifice to Agni; brief muttered prayers (Japa) and oblations of Ghee (Homa) were offered to various deities, and of water (Tarpana) to the Manes (ancestors). The food was sanctified by sprinkling with water, and portions were set aside for Brahmans, serpents, dogs, insects, and, in particular, for crows, who were believed to be the messengers to the spirit world. A few drops of Ghee would serve to sanctify the mound of rice on the plate. Only the right hand was used for eating, reserving the left for sipping water and the other baser functions of life. Food had to be broken up on the leaf with the fingers and never torn apart using the teeth.

Every item of food had its allotted place on the leaf. The six tastes present in every meal began with a sweet item, followed by salt and sour things in the middle course, and finishing with those that were pungent, bitter and astringent. One started with a liquid, then took solid food, and finished again with fluids. In actual meals that were served at the famous Buddhist monastery in Nalanda, as described by early Chinese pilgrims, two small pieces of ginger with a spoonful of salt were given first, followed by cakes and fruits. Then came a gruel of parched rice accompanied by a liquid Dhal flavoured with Ghee; this was followed by more cakes and fruits, Ghee, and some sugar candy. After the meal tooth-picks were provided. Pure water was used to rinse the mouth, and perfumed paste was rubbed over the hands before washing. Lastly were served betelnuts, nutmegs and cloves to sweeten the mouth, help digestion and expel phlegm.

A traveller, before leaving his home, made obeisance to the domestic fire, prayed, drank a consecrated beverage, and set off right foot first to take his place in the cart, which had been smeared with Ghee from the household ritual offering.

A student would leave his home to live for many years as an apprentice with his teacher. During this long period there were numerous taboos on the use of foods that might stimulate his baser appetites. When slightly older, the student would be expected to seek alms from citizens of the area to meet some of his needs of food. Of Buddhist students at the University of Nalanda in the seventh century AD, Xuan Zang writes: 'Though their family be in affluent circumstances, such men make up their mind (after their studies) to be like vagrants and get their food by begging as they go about. With them there is honour in knowing truth and there is no disgrace in being destitute.' For a Brahman student, some food restrictions would continue even after he returned home and before he married.

Food in Marriage and other Ceremonies

Food grains played an important part in the marriage ceremony, as can be seen even now among the tradition-minded Kanyakubja community. Turmeric-stained rice was tied at the top of the sacred stumbha outside, and wheat grains were pre-planted so that sprouts would be visible during the ceremony. A ritually-important Kalash (earthen pot) with a lighted lamp on it is decorated with barley grains. Kaccha foods like rice bath and vegetable curry are served at the evening meal to the close family. The priest worships the Sun and Mars with uncooked red Masura Dhal, the silvery moon with white rice, Venus with yellow-green whole Mung, Jupiter with yellow turmeric or Chanaka grains, and Saturn with black sesame seeds.

During the Vedic marriage ceremony, Lajah (parched grain) was thrown into the sacred fire by the bride with joined hands, and following the crucial circumambulatory rite of the Saptapadi (seven steps) which the bride and groom took together, they were showered with rice grains as a fertility symbol. Once she reached her new home, the bride first reverently touched the utensils there, and then set about cooking the first meal for her new family.

During pregnancy, the body was considered to be in a state of 'heat' and 'cold' and pungent foods were avoided. Periodic rituals were prescribed, which included an offering of the auspicious Madhuparka by the husband to his wife in the seventh month. After the child was born, the house was considered ritually polluted for twelve days, when no outsider could be entertained. The new mother was given specialized herbal food, rich for example in Methika or Lasuna, and on the sixth day a variety of festive preparations. Even twelve days after the birth, the mother was still not considered ritually pure enough to enter the cooking area; however, she could undertake, outside the kitchen, such operations as washing, peeling and cutting of vegetables.

A male child when born was anointed on the lips with a mixture of thick milk, honey and Ghee using a ladle of gold, along with a blessing. After about six months, on an auspicious day, the child's Anna-prasana was observed, when it was given its first solid food by way of a Paramanna of boiled rice, milk, sugar and honey. In early Vedic days, meat was also included. The kind of meat given was supposed to influence the subsequent temperament of the child; while rice and Ghee brought glory, fish yielded a gentle disposition; while ram's meat imparted physical strength, partridge meat brought saintliness.

A death in the house was a traumatic event. Till the cremation was over, all cooking, eating and drinking by the family ceased. During the subsequent days of mourning, the family lived on food sent by relatives. Frying of spices or Bagharna was especially avoided. Use of foods considered to be auspicious was abjured, such as milk and its products, Masha (Urad), Chanaka and its flour (Besan) and, in particular, the highly-auspicious Haridra (turmeric). The hearth in the house was demolished, and a new one was put up after the mourning period was over. At the Shraddha ceremony to the departed spirit that followed annually, various auspicious foods were eschewed in favour of such items as Apupas (fried sweet cakes of rice and barley), boiled Mudga (Mung), a sweet gruel of Kulattha (Kulthi), black Tila (sesame) seeds, and green Kadali (bananas).

Vegetarianism vs. Non-Vegetarianism

The *Rigveda* (about 1500 BC) has a hymn to nutrition (Pilu) which lists a large number of edible materials, all of which are vegetarian. Elsewhere in the text occur two verses praising 'the cow Adithi, the sinless', and there are no less than 16 references to it as Aghnya, meaning sinless and not to be eaten. The sacrificial animal 'destined for the gods and Brahmans' had to be a barren one. Thus there was, even in the early Vedic period, some uneasiness in regard to slaughter of animals, and especially of the cow. Yet the contrary opinion was also strongly held: the imposing sage Yagnavalkya in the *Shatapatha Brahman*, after listening to the arguments, declared his intention to continue eating beef 'because it is amshala (tasty)'.

No outright ban, but various ingenious prohibitions, marked the injunctions of the various *Dharma Sutras.* Those of Vasishtha, Gautama and Apasthamba considered milch cows and draught oxen fit for religious sacrifice, but prohibited consumption of their flesh. Baudhyayana exhorted certain penances for killing an ordinary cow, and stricter ones for a milch cow or a draught ox. These seemed to reflect a utilitarian and practical outlook rather than a humanitarian one. The *Manu Smriti* stated: 'There is no fault in eating flesh, nor in drinking intoxicating liquor, nor in copulation, for that is the occupation of beings; but cessation from them brings great merit.' Thus beef was not expressly prohibited, and the slaying of bovines (Go-hatya) was considered a lesser evil (Upapataka) than drinking of spirituous liquor (Maha-pataka). In the medical treatises, *Charaka Samhita* and *Sushrutha Samhita* eating of meat was cardinal to the innumerable dietary injunctions, and such prohibitions as there were concerned not moral issues, but the qualities of the meat in relation to body type, season and health status.

The presence in the sixth century BC of both the Buddha and Mahavira might have set the vegetarian norm for Brahman belief and practice. The Buddha was strongly opposed to ritual animal sacrifice as a means of personal salvation. However, he refrained from a total prohibition on meat eating, on the ground that begging Bhikshus should eat without question whatever food was given to them in charity. The monks themselves were absolved of the stigma of killing, and it was for the alms-giving householder to ensure that the killing was Adrstam, Asrutam and Aparivirtakam (not seen, not heard and not suspected). His follower Devadatta opposed the eating of meat and fish as implying Panita-bhojana or sumptuous food, but in the end Buddha's views prevailed.

Three centuries later, the devoutly Buddhist emperor Ashoka strongly advocated complete Ahimsa or non-killing. The Girnar rock edict in Gujarat started by declaring: 'No living being may be slaughtered for sacrifice; no festive gatherings may be held. Formerly slaughter in the king's kitchen was great; now it has almost been stopped.' Mahavira, the last of the 24 Jain Thirthankaras, was also strongly opposed to the taking of any form of life, even of germs that could not be seen; 22 things were declared inedible, along with another 32 which carried 'infinite life germs'. All drinking water was to be boiled, and reboiled every six hours, and all liquids had to be strained before drinking. Jainism thus released powerful forces in favour of strict vegetarianism.

The three later Vedic schools accepted vegetarianism as a cardinal tenet. Faced with the problem of dealing with the Vedic animal sacrifices described in such detail, Madhva declared that only an animal made of flour (dough) should be used; and Shankara and Ramanuja made do with substitutes for the animal head like the coconut or a pumpkin smeared with vermilion powder.

The result of these forces was that Ahimsa or non-killing, and its corollary of a vegetarian diet, became mandatory among the Brahman priesthood. It also entered the common consciousness, and was adopted in particular by followers of Lord Vishnu everywhere in the country.

III. FOOD AND HEALTH

The crucial role played by food in health was cogently summarised in the well-known quotation from the *Charaka Samhita*: 'Without proper diet, medicines are of no use; with proper diet, medicines are unnecessary.' Health was maintained by a well-adjusted daily diet, and ill-health could be largely tackled by a rational choice of foods. The concept and practice of this choice was embodied in the science of Ayurveda, for which a hoary origin was postulated.

Origins of Ayurveda

Brahma, the creator of the Universe, revealed Ayurveda in its entirety to Prajapathi, the primordial creative sage. From him it was passed on to the Asvins, divine twin horsemen who signified the principle of duality, and were the helpers and healers of the Vedic gods. They passed it on to Indra, king of the gods. Believing it to be too vast to transmit to a single person, Indra imparted his knowledge to four great Rishis or teachers: Atreya and Bharadvaja were taught general and internal medicine; Kashyapa mainly pediatrics; and to Dhanvantari was imparted the expertise mainly of surgery. Atreya's best pupil was Agnivesha, and it was his Tantra that formed the basis for Charaka's later treatise.

The *Atharvaveda* represented in the main a magico-religious view of medicine. It prescribed sorcery, charms, poojas and internal medication, along with some empirico-rational elements like the virtues of water, the medicinal properties of herbs, the value of products from the cow, and recognition of the bodily elements of bile, phlegm and wind. In the *Brahmanas* and *Upanishads*, elements of demonology still persisted in terms of Bhatavidya and Sarpavidya (which dealt with poisons), the Rasayana (dealing with drugs) and Vajikarana (dealing with potency).

Then followed a profound conceptual change, caused largely by the emergence of three systems of philosophy. Samkya postulated a relationship between the elements of nature and those of man, between intellect, ego and mind, and between the five cognitive and five connative organs, which were the Panchabhutas and their subtle states. Nature represented a harmonious blend of three strands of Gunas or qualities, comprising the essence of all that was good and noble (Sattva), all that was energetic (Rajas) and all that represented inertia (Tamas) and man, too, was composed of these same three qualities. The Nyaya-Vaiseshika philosophy rested on the reliability of reason and the unity of analysis, both logic and dialectics. The external material world was necessarily received by the mind, but existed independent of it. The entities that the system admitted were taken directly from experience, and abstract thought had no place. All things in the world were made up of six Padarthas, or irreducible substances. These were dravya or independent substances; Guna or qualities like Rasa (taste), Rupa (colour), Gandha (odour), Sparsh (touch) and Shabda (sound); Karma which stood for movements of various kinds; Samanya or sameness; Visesha or perceived differences; and Samavaya which connoted inseparable principles which co-existed or inhered as one reality.

When Ayurveda (ayur = life, Veda = knowledge) came to be formalized by Agnivesha about the sixth century BC, it represented in essence the practical application of these Nyaya-Vaiseshika philosophies to everyday life, to the knowledge of how to live. The *Agnivesha Tantra* formed the basis for the classic work of Charaka (meaning the wanderer), who may have lived and taught at about the start of the Christian era at the medical faculty of the University of Takshsila in Punjab. Though the title of his work, *Charaka Samhita,* was retained when it was revised by Dradhabala in the ninth century AD, a vast amount of accrued material was incorporated into it from Kalpas (monographs), specialized treatises (Tantras), and floating knowledge among various medical schools. What was present in Charaka's original treatise, and what was added later, is now impossible to disentangle.

Two other books codified Ayurvedic thoughts and applications. The *Sushrutha Samhita* was first put together perhaps a century after that of Charaka by a scholar-doctor in the court of Divodesa, who was king of Kashi and himself a doctor. It dealt primarily with surgery, but also with Ayurvedic principles in general, which of course included dietetics. The *Ashtangasamgraha* and *Ashtangahrdya* were both by Vaghbhata, who might have been a single person or two. It was a two-volume work which was a digest of the eight parts of Ayurveda, synthesizing the Samhitas of both Charaka and Sushrutha. These three pillars of Ayurvedic science were collectively referred to as Vriddha-trayi.

Ayurveda represented a system of rational medicine that sought directly perceptible results: 'Even a thousand logical grounds will never cause (a certain group of herbs) to have a purgative action in practice.' Anyone wishing to have a thorough knowledge of anatomy 'must prepare a dead body, carefully observe (by dissection) its different parts, and examine them; for a thorough knowledge can be acquired only by direct personal observation'. Further, 'Of all types of evidence, the most dependable ones are those that are directly observed by the eyes.' The *Charaka Samhita* even had a section entitled Vimana-sthana, literally meaning a section on specific proofs. It was designed to explain the methodology of science. Another whole chapter, entitled Roga-bhisag-jitiya-vimana, dealt with the logic of debates, which were strongly urged on all physicians to gain new knowledge, clarify thinking, remove doubts and strengthen convictions. In fact, the entire *Charaka Samhita* appears to represent a collection of discussions of learned physicians with Atreya as chairman!

The Basis of Ayurveda

The bedrock of Ayurvedic thought was the parallelism perceived between the Universe as macrocosm and the individual body as microcosm. Thus, the principles, forces and substances which supported the activities of the Universe had counterparts that caused the body to function. The Sun, Moon and air pervaded the Universe. The Sun bestowed heat and energy; its representative in man was the force named Pitta, which controlled all body processes, like digestion and metabolism, leading to the production of heat. The Moon stood in a relationship of tension to the Earth, ruling the tides and acting on biological rhythms; it had an affinity with water in the body, where it was represented by Kapha, which altered the equilibrium of fluids in the tissues. Wind was the movement of the atmosphere, and Vata, the principle of movement in man, was centred in the complex nervous system with all its impulses.

Further, the Universe was believed to be composed of five ingredients or elements, the Panchabhutas: Prithvi (earth), Jal (water), Tejas (fire), Vayu (wind or air) and Akasha (loosely translated as ether or space). Earth was characterised by Gandha (odour), water by Rasa (taste), fire by Rupa (colour), wind by Sparsha (touch) and Akasha or space by Shabda (sound), which were related to the five human senses of perception. In the body, the five elements were modified to give seven Dhatus or building blocks which upheld it. These Dhatus were formed from the pure portion of the food ingested, called Ahara-prasada: in turn, this yielded in the body Rasa (food juice), Rakta (blood), Mamsa (meat), Medas (fat), Asthi (bone), Majja (bone marrow) and Shukra (semen). Cast off as by-products of these transformations were the waste products or Malas, like wine, faeces, sweat, hair, nails and so on. Also, among the digestive products were the three Doshas, which were themselves constituted of combinations of five elements: Vata of space plus wind, Pitta of only fire, and Kapha of earth plus water.

These three Doshas needed to be in equilibrium for the body to be in health, and it was essentially food that brought about this equilibrium: 'Beneficial food is the cause of growth of a person, and injurious food is the cause of disease'. Nor was this only physical disease. The combined presence of such Doshas also determined a person's temperament or Prakriti. Temperament was of seven different types, according to the Doshas that were deranged, singly or severally, and it was determined at the time of a person's generation. Any disturbance in the three Doshas or matter principles sparked off a chain reaction that could manifest itself in the three components of the human psyche: Buddhi or intellect, Ahamkara or ego, and Manas or mind/spirit. Changes in the Tridoshas—Vata, Pitta and Kapha—could be restored to alignment by foods or drugs that possessed the opposite attributes, administered according to considerations of place, measure and time.

Food Digestion and Metabolism

Charaka defined a substance or Dravya as something that possessed quality (Guna) and action (Karma) in a relationship of togetherness or inherence, and it was also the inseparable material cause (Samvayi-karana) of all effects. Gunas were the ultimate qualities, and were themselves inactive. The action of the substance was Karma, and its potency Virya; the place where it operated was Adhi-karana, and the time of operation was Kala; the alteration in quality following digestion was Vipaka, the mode of operation was Upaya; and the result achieved was Phala. All these were manifested first in the digestion of the food, and then in its further mobilization in the body.

For thorough digestion of food, a fine substance in the form of a juice called Ahara-Rasa was produced, which was imbued with energy and fire. When food was eaten, it was seized by the Prana or life-breath and sent to the stomach. Solids were broken down by liquid juices and softened by oily matter. Then the Agni (digestive fire), fanned by the Samana or life-breath, blazed forth and digested the food to yield both Rasa and Mala (waste products). The six Rasas present in all foods began to be digested from the very start followed by a sweet reaction leading to the release of a foaming Kapha. As digestion proceeded to the half-way point, a sour reaction set in, and the mass passed from the Amasaya (stomach) to the Pakvasaya (small intestines), where it was further digested by release of Pitta. When the mass further descended into the large intestines it got compacted; a bitter and astringent reaction then set in, and Vata was generated.

From the small intestines, the Ahara-rasa was driven by the Prana-vayu along Dhamanis, which were ducts for the passage of fluids, first to the heart and then along other Dhamanis to every corner of the body. As it moved on, the body constituents were produced. Each Dhatu derived from the previous one: first blood (from Ahara-rasa itself), then flesh, then fat, then bones, then marrow, and finally semen.

The entire digestive process was described as one of cooking (Pakana), first by the digestive fire, Agni, and then in turn by the other five fires, the Bhutagni. The outcome of digestion was that the five Bhutas locked up in all foods were released, and proceeded to join and renew their counterparts in the body. The Malas or waste products from these operations were not harmful in proper measure and might even perform useful functions, but a defect or excess of any of them called for corrective action.

The significant waste products of the digestive process were none other than the three doshas—Kapha, Pitta and Vata. Kapha was the offshoot of the early sweet digestive reaction; Pitta was that of the subsequent sour digestive stage; and Vata was that of the bitter and astringent, compacting phase. The special seat of Kapha was the throat, of Pitta the stomach, and of Vata the bladder and intestines—though various other organs also generated them in lesser amounts.

The strength of the digestive fire varied in different individuals, and this, besides other factors like the season of the year, determined the quantity of food that each person ought to consume. There were some general rules: until one meal had been digested no other should be taken. The amount eaten should be just enough to give satisfaction (Trupthi) rather than to cause satiety. Normally only two meals a day were to be eaten, one in the morning and the other in the evening. The stomach was visualized as consisting of four parts: two parts could be filled with solid food and one with liquid, leaving one part empty for the movement of Vayu (wind).

Some indication of quantity and dietary balance is provided in the *Arthashastra* of Kautilya, which noted that a gentleman's meal should consist of one Prastha of pure unbroken rice, one-fourth of a Prastha of pulses, one-sixth of a Prastha of Ghee or oil, and one-sixty-fourth of a Prastha of salt.

Food Types and Classes

Food in general was termed Ahara. It was classified in several ways in different contexts. Vargas, or food classes in common culinary terms, frequently numbered thirteen: cereals (Sukhadhanya), legumes (Samidhanya), vegetables (Shakna), tubers or 'vegetables growing underground' (Kanda), fruit (Phala), nuts (Bija), alcoholic liquors (Madhya), water (Jala), milk products (Paya), sugarcane products (Ikshu), fats and oils (Thaila), spices (Soopyam) and flesh products (Mamsa). Both raw materials and prepared foods are thus included.

Another four-fold physical classification applied to food as consumed. Carvya or foods of normal consistency (Asitam) were eaten by mastication; liquid foods (Pitam or Peya) were drunk; chewable crisp foods (Khadinam) were termed Cushya; and Lehya signified lickable foods (Lidham). Ordinary rice and wheat breads came under the first chewable category. Liquid foods included milk, fruit juices, soups and the like. Crisp foods were nuts, Parapatas (Papads), etc. Lickable foods included honey, chutneys, sauces and many relishes.

In terms of health, foods were grouped as Pathyam or Apathyam. Pathyam foods were those that did not adversely affect the body and mind when taken in moderation at the proper time; apathyam foods had a contrary effect. Pathyam substances, which could be taken as regular, everyday foods, were Shali rice, green gram, rainwater, rock-salt, Jeevanthi or Dori (*Leptademia reticulata*), Patola or Parwal (*Trichosanthes dioica*), deer meat, Lava birds, Rohita fish, Ghee and milk of cows, sesame oil, pig fat, ginger, grapes, wheat and Amalaki. Foods generally considered Apathyam, which should not form part of the daily diet were sea-salt, black duck, frog meat, Chilichima fish, sheep milk and ghee, safflower oil, fats of buffalo, crocodile and elephant, radish, jack-fruit and molasses (Phanita).

Such classification as beneficial and interdicted foods assumed special importance in pathological conditions. For example, in conditions of hyperacidity (Amla or Pitta), Pathyam foods included old paddy, wheat, green gram, bitter gourd, Patola, grapes, curry of plantain flower, Amla, pomegranate and lime chutney, boiled and cooled milk, cow's milk, dates, ghee and honey. Apathyam or unfavourable foods in hyperacidity were all very sour, bitter, heavy and oily foodstuffs, besides items like curds, sesame seeds, Thuvar Dhal, black gram, peas, goat's milk, carrots, new jaggery and salt.

A classification of food, that was related to overall Ayurvedic concepts, was based on the five Bhutas or basic elements of which all matter was believed to be composed. In this ambience foods were classed, depending on which Bhuta predominated, into five categories; Parthiva (earthy), Apya (watery), Agneya (fiery), Vayavya (airy) and Akasatmaka (ethereal). This classification served to explain the effects that various foods exhibited in upholding or pacifying the equilibrium of the three Doshas in the body.

IV. GUNAS OF FOOD

Broadly speaking, Guna is the property of a substance, which exists, for example in a food material, in an inseparable condition of inherence. Of the many Gunas of food, that of taste was by far the most important; there were six kinds of taste, to which we shall return. As regards the other Gunas, ten contrasting pairs in the context of food could serve to explain their action on the body. These were: Guru-laghu or heavy-light; Sita-ushna or cold-hot Snigdha-ruksa or oily/viscous-dry/rough; Manda-tiksna or mild/slow-keen/quick; Sthira-sara or compact-mobile; Kathina-mrdu or hard-soft; Picchila-visala or slimy-clear; Slakshna-kara or smooth-rough; Sthula-suksma or gross-fine; and Sandra-dravya or solid-liquid.

Both taste and Guna determined the effect of a food material. Sometimes a Guna could even dominate the effect of Rasa. Thus cold water, being sweet, stimulated and strengthened Kapha. But hot water, while still sweet, had an added hot or Ushna property, and would pacify and reduce Kapha. Similarly, the Amla fruit had a sour taste, but the effects that it exerted were much intensified by its also being Sita (cold) and Mrdu (soft).

Rasa was the main basis for the choice of a food material for consumption, but Guna served to guide both internal and external use. Thus, while the property of oiliness conferred in internal use a laxative and lubricating effect, it was oiliness that was the basis of external effectiveness as a massage. Again, the hot or Ushna quality in consumed food could regulate digestion by strengthening the digestive fire Agni; when applied externally as a hot poultice, Ushna served to relieve cramps and draw pus out of boils.

The Rasas of Food

The six basic Rasas or tastes were considered sufficient to cover all foods, though combinations of tastes were of course common. The six Rasas were Madhura or sweet, Amla or acid, Lavana or saline, Katu or pungent, Tikta or bitter, and Kasaya or astringent. Each of these tastes was once again regarded as being constituted of combinations of the five basic building-blocks or Bhutas, of which all matter was composed. Madhura was composed of earth and water, Amla of earth and fire, Lavana of water and fire, Katu of air and fire, Tikta of air and ether, and Kasaya of air and earth. Since the three bodily Doshas were constituted in the same manner, specific tastes would either weaken or strengthen them. Thus the Dosha Vata would be weakened by sweet, sour and bitter Rasas, and strengthened by pungent, bitter and astringent ones. Similarly, Pitta was weakened by sweet, bitter and astringent tastes, and fortified by sour, salty and pungent ones. Kapha was assuaged by pungent, bitter and astringent tastes, and strengthened by sweet, sour and salty ones.

There were some complicating factors. In certain instances, the apparent and even obvious taste of a substance was believed to be altered in the course of digestion, an effect which was termed Vipaka. The six Rasas were believed to get reduced after Vipaka to only three. Sweet and sour tastes became sweet, and bitter and astringent ones became pungent; only the sour taste remained sour even after digestion. It was the Vipaka taste that would exert its effect on the Doshas.

Another factor was the power of the food material to produce effects in the body, which was its potency or Virya. Virya was clearly important where a medical effect was being sought, whereas Rasa would have greater significance in daily dietary terms.

On rare occasions, a substance might act in a totally unpredictable way. For example, two substances practically identical in terms of Rasa, Vipaka and Virya might exert very different effects on the body, a phenomenon which was termed Prabhava.

Apart from the factors of Rasa, Vipaka, Virya and Prabhava, the other Gunas of any foodstuff would play their part in its final effect on the Doshas. The Dosha Vata was aggravated by excessive use of bitter, pungent, astringent and dry food, dry meat, and by the use of certain legumes and rice in combination. Pitta Dosha was inflamed by an excess of pungent, acidic, salty and dry food, and by the excessive use of sesame seed, mustard seed, sesame oil, linseed oil, fish, mutton, certain leafy vegetables, wines, curds and whey. The Dosha Kapha was aggravated by partaking of too much sweet, acidic and salty food, food that was cooling, heavy and oily, and by too much use of milk, curds, sugar, fats, wheat cakes, sweet fruits, and meat of aquatic animals.

Food Effects in Terms of Rasa

Foods of the sweet group were in general supposed to increase body Dhatus, improve complexion, strengthen the body, heal wounds and ulcers, and purify the blood. Those belonging to the acid group were as a class carminative and digestive; they expelled wind from the bowels, and accumulated secreted impurities in the tissues. Foods of the saline group purified the tissues, and were digestive; they accumulated excretions in the system, relaxed body tone, cleared the outlets, and produced softness in all body structures. Pungent foods increased digestive power, purified the body, promoted corpulence, caused ligaments of the joints to relax, and diminished the formation of milk, semen and fat. Those of the bitter group separated the three Doshas; were appetizing, digestive and purifying; improved the secretion of breast milk; and reduced the quantity of faeces, urine, sweat, fat, marrow and pus. Finally, the astringent foods as a class were styptic, helped heal ulcers, checked all discharges, regenerated impurities from tissues, and reduced corpulence and superfluous moisture.

Let us now consider individual foodstuffs under each Rasa:

Madhura foods: Staple cereal grains were considered predominantly sweet. Rice acted positively on all the three Doshas and was sweet, cooling, diuretic, beneficial to the eyesight, strengthening, and a heart tonic. Only those with stomach ulcers and diabetes had to avoid it. Winter or Shali rice was particularly commended, while the poorest kind was the monsoon rice Vrihi. Old rice was more easily digested than new. Whole wheat gruel was indicated for heartburn, eructation, stomach upsets, colitis, and stomach and bowel cramps. Wheat germ was also excellent in these conditions, strengthening Kapha and calming Vata. Wheat bran cleansed the bowels and tranquilized all the three Doshas, and would soothe an irritated skin caused by an upset Pitta. Barley gruel was good for gastro-intestinal troubles, and barley flour cooked in milk stimulated lactation. Rye was recommended for older people with a sluggish blood flow.

All tubers also belonged to the Madhura group, like sweet potato, tapioca, yams, taro and aroids. Legumes as a class were sweet foods, but reinforced Vata, and had to be reduced in the diets of people of this temperament. Oilseeds, vegetable oils, animal fats and nuts were all basically sweet foods that mitigated excessive Vata. Ghee mitigated all the three Doshas, even those of the mind, improving memory and stabilizing intellect. Old Ghee had special tonic and rejuvenating properties, and the older the better. Cow Ghee was rated highest on all counts, while goat Ghee was easily digested and soothed Kapha. Ghee from human milk improved eyesight and acted as an antidote against poisons.

Milk and its products also belonged to the sweet-tasting group. Milk was heavy, fatty and cooling; it contained the Rasas of many plants and was therefore a life-giver. It was particularly good for children and the elderly, the thin and the convalescent, and all those whose digestive fire was weak. Milk was best drunk warm at night, when it allayed the sensation of heat generated by the day's food. Cow's milk was considered the elixir of life, and when drunk warm, calmed all the Doshas and especially Pitta. Goat's milk was highly rated, especially for children, and was found useful in diarrhoea, tuberculosis, bronchitis and fever. Sheep's milk, drunk hot, soothed a disturbed Vata, as did mare's milk. Human milk was always taken cold and had a strengthening effect.

Flesh foods too were essentially sweet, but had a heavy Guna. The meat of animals from arid Jangala terrain had a Vata-enhancing effect, while the flesh of those from watery tracts helped regulate Kapha.

Sugars obtained from sugarcane, coconut and date palm were all sweet foods which promoted the excretion of waste products, and were recommended in kidney and liver conditions. Fruits were also generally of sweet disposition, but had a sour taste after digestion.

Honey, an obviously sweet food, was not taken at face value in Ayurveda; it was considered principally astringent in its effects, increasing Kapha and causing weight-reduction, unlike sweet foods in general.

Nuts like almonds and walnuts were also Madhura foods, as were coconut meat, copra and coconut oil. Coconut water was cooling, aperient and diuretic, valuable in kidney complaints and in depleting dropsy.

Acid foods: These were heavy, hot, oily, diaphoretic, appetizing and cleansing. They strengthened Kapha and Pitta, reduced Vata, and corrected digestive disorders. Over-indulgence in sour foods would bring on illnesses resulting from an increase of Pitta. Sour foods included mango, pomegranate, tamarind, grapes, citrus fruits like citron (Matulunga), lime, lemon and orange, karumarda (*Carissa carandas*) and Parusaka (Phalsa). Amla, though essentially sour, was also pungent, bitter, astringent and sweet; it strengthened the liver, was cooling and mildly laxative, and beneficial in Pitta disorders. It was one of the three constituents of the anti-debility powder Triphala, together with equal proportions of two Kasaya (astringent) fruits, the Haritaki and Vibhataki; the product of Triphala digestion was considered sweet, and it helped in disorders of all three Doshas.

Salty foods: The Lavana group of foods stimulated Pitta and Kapha, and reduced Vata. The effect of salt foods on waste products (Mala) was aperient and diuretic, and helpful in expelling wind. Salt foods cleansed the body ducts (Srotas). However excess salt in the diet brought on diseases resulting from an increase in Pitta and Kapha, such as aging of tissue cells, skin diseases, and hair loss. Various types of salt like rock salt, alkaline salt (Romaka Lavana) and sea salt had differing actions on the body. Sea salt was heavy and not particularly heating, and it did not bring on a burning sensation. Rock salt stimulated digestion and had a calming effect on all the three Doshas; though a salt, it was considered cooling and not heating.

Pungent foods: The Katu taste caused the tongue to tingle, inducing salivation and tears. It strengthened the digestive fire, Agni, sharpened appetite, promoted digestion, calmed Kapha and increased Vata. Most spices came under this group. Equal parts of ginger, long pepper (Pippali) and round pepper (Maricha) constituted Trikatu, given in Kapha and Vata disorders. Dried ginger or Sunthi was considered light and oily, but fresh ginger or Adhraka was heavy, drying and penetrating. The taste after digestion of ginger was sweet, so that unlike most spices, it could be used by persons in whom any one of the three Doshas predominated. Fresh ginger with a little lemon juice and a pinch of salt chewed fifteen minutes before the main meal was supposed to stimulate all the thirteen digestive fires. Ginger helped in both chronic diarrhoea and chronic constipation. Pepper suited people of Vata and Kapha temperament, but not those inclined to Pitta. It sharpened the appetite, helped digestion, and expelled wind. Garlic carried five of the six Rasas, only the acid taste being absent. It was considered oily, keen, slimy, heavy and mobile; it expelled wind, inhibited the growth of Krmi (germs) and soothed inflammation. The onion was extremely pungent and noticeably sweet after digestion; though stimulating and diuretic, it was little used in Ayurveda. Other Katu spices were black mustard (Rajika), asafoetida (Hingu), Tulasi, Jatiphala (nutmeg), and betel-leaf (Tambula), each having specific effects on the body.

Bitter foods: Tikta foods reinforced Vata and reduced Pitta and Kapha. They depleted the elements of fat (Meda), of flesh (Mamsa) and of marrow (Majja), and counteracted the causes of Madhumeha (diabetes). Bitter food materials purified the blood, removed pus, and benefited in such conditions as skin diseases, poor appetite and burning sensations. Five products of the Neem tree (root, bark, leaves, flowers and fruit) constituted the Panchanimba, used for Pitta disorders. Turmeric was bitter, but also pungent and astringent, with a pungent after-digestion effect; it was stomachic and regulated the appetite, allayed sore throats, cough, cold and chills, and assisted diabetics. Other bitter foods that benefited diabetics were Methi (fenugreek), Karela (bitter gourd) and fruits of the purple Jamoon. Most spices and condiments were Tikta foods. There were many other bitter materials, which were more medications than foods, with specific and unaccountable actions (Prabhava).

Astringent foods: Kasaya foods were light, cold and dry; they were considered to produce clarity, reinforce Vata and reduce Pitta and Kapha. Astringent foods aided the whole healing process, particularly in exposed wounds, burns, skin diseases, diarrhoea and dysentery. Kasaya medicines were frequently the barks and exudates of trees; the Kattha smeared on betel leaves was an astringent. Two components of Triphala, a strengthening powder, were astringent, and the third, the Amla fruit, acidic. Honey, though obviously sweet in taste, was treated in Ayurveda as astringent in action, owing to its Vipaka taste; accordingly, it reduced Kapha and with it obesity.

V. OTHER FOOD CONCEPTS

Food and Seasons

Charaka said: 'He who understands and follows the dietetic regulations for each season by seasonal variations of his diet improves his complexion and increases his vigour.' The year was divided, in the Ayurvedic tradition, into six seasons of two months each, and dietary modification by season was termed Rtuchavya. Vata was said to be aggravated in the cold and rainy seasons, and especially on cold and stormy days; Pitta in summer and autumn; and Kapha in winter and spring.

During the cold season (Hemantha), from 15 November to 15 January, the digestive power was strong, and recommended foods were fats, sour and salt sauces, the flesh of water and marsh animals and of goats, and similar heavy foods. Liquor, milk preparations, sweets, fats, oils, new milk and hot water could all be used. Other injunctions were to use ointments on the skin, to undergo massage, to anoint the head with oil, and to stay in a warm room, or in the sunshine, or in a warm underground place, or in an inner room. In the season of dew (Shishira), lasting from 15 January to 15 March, one had to seek even warmer and rooms better protected from the wind, and to avoid foods and drinks that were pungent, light and cold. During these two seasons the body was at its best.

Following them was the season of flowers (Vasantha) or spring, from 15 March to 15 May, when the Kapha that had accumulated in the two earlier seasons provoked many disorders. Emetics were advised, but food that was heavy, oily, sour and sweet had to be avoided. One should not sleep by day, should bathe in cold water, partake of exercise, massage and inhalations, gargle with water and use ointments. In terms of food, barley, wheat and the meat of stag, hare, antelope and quail were recommended, as were certain kinds of liquor.

During the summer season (Grishma), from 15 May to 15 July, the digestive power was at its lowest ebb; tasty, cold, fluid and oily food items were recommended, like cold preparations of barley with milk and sugar, deer meat, ghee, milk and rice. Spirituous drinks were best avoided altogether, or taken much diluted. One should avoid salty, sour, hot and pungent foods, physical exercise, sleeping by day in a cold place, and cohabitation. At night one should sleep in a place cooled by the rays of the moon, particularly on the windy roof of the house, and anoint the skin with cooling sandal ointment.

The rainy season (Varsha) lasted from 15 July to 15 September, and the digestive system was still weak. One should keep to a diet of barley, wheat and old rice with venison and boiled sauces, use medicinal liquor in small doses with honey, and drink rainwater or boiled water. Interdicted were sleeping by day, physical exercise, cohabitation, and exposure to the heat of the sun; while recommended practices were massages, baths and residence in a dry place.

Finally came the autumn (Sharad), from 15 September to 15 November, a time to eat in moderation sweet, light, cold, bitter and other items that were deficient in Pitta, like venison, rice, barley and wheat, while using pure water from a spring for washing, drinking and bathing. Among foods to be avoided were bitter drinks, Ghee, fats and oils, while things to be abjured were purgatives, bloodletting, and the east wind.

These seasonal prescriptions needed to be modified in relation to the individual constitutional type. If Vata predominated, one should in each season indulge in only such food, drink and living habits that did not excite that Dosha but kept it in its proper state. The same was true when either Pitta or Kapha were dominant. Each Dosha derangement could have many causes, both of diet and life-style. Vata was disordered by eating acid, astringent or bitter foods, foods that were light, dry and cooling, dry herbs, dry meats and certain cereals and pulses; also by too little food, irregular food habits or excessive eating. Life-styles that exacerbate Vata included excessive physical activity, venery or study, fighting with strong people, running, falling from a height, excessively strong massage, injuries, fasting, remaining in water, swimming, staying up at night, carrying heavy weights and excessive riding or walking. Faeces, vomiting, sneezing and eructation all inflamed Vata, while it was exceptionally deranged by cold, in seasons that were cloudy, windy and rainy, every morning and evening, and after digestion of food.

Pitta derangement could be caused by use of acid, salty, pungent, hot, light and indigestible articles of food, like sesame oil, oil-cakes, Kulattha, mustard seeds, linseed, meat of iguana, goat and sheep, fish, cooled milk, buttermilk, whey, fermented barley water, alcoholic drinks, acid fruits, and acid and fermented liquors. Anger, grief, fasting, indigestion and excessive sexual indulgence were the other causes. Pitta was generally deranged at midday and midnight, and when food was being digested. It was especially deranged by heat, and in summer and autumn.

The third Dosha, Kapha, was enhanced by the use of sweet, acid, saline, cold, heavy, oily, emollient and demulcent articles. These included certain varieties of rice, barley, wheat, a gruel of ground sesame seed, curdled milk, rice and milk boiled together, sugarcane juice preparations, the meat of animals living in water or marshes, fat, water-lily tubers and sweet fruits of creepers. Full meals, eating again soon after a meal, illness, want of exercise and sleeping during the day all tended to derange Kapha. It was especially prone to disorder in winter and spring, in the morning and evening and immediately after eating a meal.

Food and Habitat

According to *Ayurveda*, the specific nature of a substance, its Prakriti, was modified by the place (Desa) in which it was grown and the time (Kala) at which it was generated. Three kinds of land tracts were postulated, and each had its own kind of influence on the Doshas. Ordinary or Sadharana land was indifferent to them, but arid Jangala land chiefly produced Vayu in humans and swampy or marshy land (Anupana) increased Kapha (phlegm). Of even greater practical importance was postulated that the flesh of edible creatures that lived in such types of land carried these attributes as well. The flesh of animals living in Jangala land increased Vata, while it was Kapha that was stimulated by the meat of animals that lived in marshes. Each land type included several groups of animals. Thus the Jangala group of animals included those living in burrows and caves, and also domestic creatures. The latter had flesh that was sweet and rather astringent, lean and light, energy giving and stimulating to the appetite. Such flesh reduced all the three Doshas, but particularly Vata. The Anupana group included animals that lived close to the water, besides swimming creatures and fish; the flesh of these was sweet, fat and heavy, which reduced the digestive fire and helped regulate Kapha.

The properties of milk were influenced by the place where the animal grazed. The richest and heaviest milk was from lush hilly meadows, while light and less-creamy milk derived from animals that foraged in low-lying, water-logged and parched fields. Even the time of the day had an influence. Milk drawn from an animal in the evening after it had foraged all day was very wholesome and tempered all the three Doshas. Morning milk was cold and thick; it caused lassitude and drowsiness, made a person dull, and increased Kapha. Drunk in the morning after boiling and cooling, goat's milk reduced Vata and Pitta.

Even with plants, the place of growth, the season and the time of gathering the plant product were postulated to influence their nature (Prakriti) and potency (Virya). Thus, the banks of rivers, termed 'land that is beaten by foam', were recommended for growing pumpkins and gourds; land that was frequently under water was to be used for long pepper, grapes and sugarcane; the vicinity of wells was suitable for vegetables and roots; low ground in moist beds of lakes was good for green crops; and marginal furrows between any two rows of crops were recomended for herbs and certain tubers. These injunctions reflected both agricultural and health desiderata.

Compatibility and Incompatibility

Certain foods were recognized as not conforming to Ayurvedic theory. Milk, a sweet food which was considered heavy, fatty and cooling, was expected to increase diarrhoea but given in regulated amounts, it can cure diarrhoea of certain kinds. This was sought to be explained on the basis of treatment by similars (Samanya). Flesh foods were regarded as being sweet, and remaining sweet after digestion (Vipaka): this should make them cooling, and yet they had a distinct heating effect on the body. Pulses or legumes, despite the presence of body-building constituents, reinforced Vata, and were indeed required to be cut down in the diets of predominantly Vata types.

Some basic properties could be reinforced, naturally or otherwise. The Amalaki was the classic example of a sour taste, but it was also pungent, bitter, astringent and sweet. Its after-taste was sweet, and its potency (Virya) cool, both of which powerfully reinforced its effect in stimulating the appetite, promoting digestion, expelling wind, strengthening the liver and helping in diarrhoea and dysentery. The tempering effect of foods was also important in practice. Particularly hot foods, like mangoes and jack-fruit, were best accompanied by milk to moderate their resultant effect.

Certain food combinations were strongly believed in Ayurveda to be incompatible (Viruddha). One concerned honey and milk. Use of milk with salt or sour foods was believed to lead to skin disease. Use of milk with fish was interdicted: one being cold, the other hot, this incompatibility could vitiate the blood and cause obstruction of the channels. Honey also was never to be taken along with salt, or even with certain acid fruits, on pain of 'death or loss of strength, complexion, radiance, virility and potency'. Use of honey with Ghee was also banned. The flesh of domesticated animals, whether land or aquatic, was not to be eaten in conjunction with honey, sesame, milk, black gram, garden radish, lotus stalks or sprouted grains, the price to be paid being 'deafness, blindness, idiocy and faltering of speech'.

The nature of the vessel in which food was cooked influenced the nature of the resulting product. Rice cooked in a copper vessel destroyed Vata and was good for spleen diseases. Food cooked in a bronze vessel destroyed diseases caused by Vata and pacified all the three Doshas. Rice cooked in a silver vessel removed Pitta, and benefited the digestion. While a tin-cooked product rendered the body cool. Rice cooked in earthenware suppressed biliousness. A pot made of earth drawn from Jangala land yielded cooked rice which was good for the blood, skin diseases, itches and wound-healing; a product cooked in a pot made from Anupana earth was conducive to digestive strength and to pleasure; and if the earth came from wild and marshy Sadharana land, the cooked rice alleviated bile and phlegm.

Food as Therapy

For biliousness, caused by deranged Pitta, coconut water was recommended, and for fever, thirst and indigestion, barley water. In convalescence or slight fever, boiled rice with lightly-seasoned meat was advised, and during fever, the juices of tender radish, Patola (Parwal) and Neem. Loss of appetite, debility and thirst could be countered with a suspension of parched barley or rice in water that was then sweetened with honey or jaggery, or with buttermilk containing bitter juices. In dysentery milk was a veritable Amrutha. Vomiting called for milk, meat soups, light cereals and tender vegetables. When intestinal worms were present, forbidden foods were milk, meat, Ghee, green leafy vegetables, curd and sweet or acid substances. Dyspepsia called for fruits, cooked roots, tasty beverages, and sweetmeats made with acid juices.

Frank medical conditions had their dietary injunctions. For tuberculosis, the flesh of active animals was recommended, like that of the crow, vulture, mongoose, cat, cormorants and beasts of prey, all fried in mustard oil; alternatively, that of the camel, ass, elephant, mule, horse or forest-dwelling herbivores could be used. Both goat milk and goat Ghee were particularly useful. Asthma was considered a disorder of excess Kapha, that could be brought on by too much Madhura food. Pungent or astringent foods were the antidote, in the form of extracts of chicken, pigeon and wild fowl cooked with large quantities of acid juices, salt, goat Ghee, and honey, an astringent food. Among the drugs recommended were Kustha roots, Kantakari (*Solanum xanthocarpium*), and roots and leaves of Arka (*Calotropis gigantea*).

Diabetes was essentially a condition in which Vata was depressed and Pitta and Kapha were elevated, so that a katu (bitter) antidote was called for. Turmeric had a very positive effect, as did asparagus root, bitter gourd (Karela), and the meat of domestic animals. Bitter seeds of the Jamoon (*Syzygium jambos*) and Triphala, the three-component myrobalan mixture, were specific medications. Jaundice too was treated with bitter materials, and with drugs such as the rhizomes of Kutaki (*Picrorhiza kurroa*) and certain roots. Malaria called for round pepper and Tulasi leaves (*Ocimum sanctum*) and the bark of Saptaparna (*Alstonia scholaris*). Dried ginger, black pepper in milk and turmeric were all common foods helpful in rheumatism, along with external anointing with lemon-grass. A recommended drug was the Guggulu exudate (*Commiphora mukul*), with astringency as its principal taste, and bitterness as the after-taste.

Other Components of Ayurveda

The object of Ayurveda was to assist nature by supporting its processes in a broadly three-fold way: Anna or strict dieting was a major aspect of Ayurvedic treatment; Aushada, the use of medicinal plants and drugs, was another; and various exercises or Vihara was the third. In practice, the first step was to excrete accumulated waste quickly, either by emetics which emptied the stomach and increased Kapha; or by purgatives which cleared the small intestines and increased Pitta; or by enemas which washed out the rectum and colon and increased Vata. The next step was to calm the excited Doshas so that the disease processes ceased. Kapha was calmed by diets, medicinal plants and therapies that involved pungent, bitter and astringent tastes, and keen, hot and dry properties; Pitta was calmed by bitter, astringent and sweet tastes and by cold, mild, solid and compact properties; and Vata was subdued by salty, sour and sweet tastes and by hot, oily, heavy, compact and slimy properties. The third step was to improve the health by exercises and mental conditioning against the sickness so as to help build up the individual's own power of resistance.

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Section Two

TECHNOLOGY

CHAPTER IX

A Perspective on Technology in India

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I. INTRODUCTION

Humans throughout history have been creating and recreating conditions of their existence. They interact with nature and in doing so generate knowledge and create artifacts, which change the conditions of human existence. The intervention with nature, with its ecological balance, thus plays a critical role in shaping their future, The positive aspect of human intervention with nature is beautifully described by Iqbal in his Persian poem, 'Dialogue of man with God':

> Man says to God: You created the mountains and the deserts
> I created the beautiful parks and gardens.
> You created the night I created the lantern
> I am the one who created mirror from stone.

The capacity to intervene with nature is based on the technological capacity humans are able to generate. This capacity also generates dreams (or fantasies) to go beyond nature, to soar higher and leave behind for generations to come a technological capacity that a society can acquire or a ruler can control to build structures to commemorate his achievements. The Ctesiphon Arc of Babylonia (in Iraq), the Pyramids in Egypt, the caves of Ajanta, the Greek temples, and the Roman amphitheatres and aqueducts are all reminders of this human tendency to aspire. We see similar aspirations reflected in the architecture of the medieval period, and construction of temples, mosques, cathedrals, forts, palaces, and mausoleums, where human dreams had their expression through technological capabilities blended with religious beliefs and aesthetics to shape life and the quality of living. These constructions became possible as a result of development of agricultural technology, irrigation and hydraulics, which provided the necessary surplus for such achievements.

A major change in the condition of existence was brought about by the industrial revolution with the introduction of iron as the basic construction material, for creating machines as well as for building iron bridges, structures like the Eiffel Tower, railroads, telegraph and telephone lines, etc. as an expression of the possibilities the new material opened up. In contemporary society the new conditions of existence have been created by information technology, bio-technology and space technology, along with the related technologies required to support them. Man on the moon and rockets soaring into space reflect not only human ingenuity but also the fulfilment of man's dreams.

In the new dialogue with God (in terms of Iqbal), man might well say: 'Look what you gave me and what I have created and where I have soared!' And God might well retort: 'Look also at what you have lost! By your achievements you have unbalanced the ecology, endangered your own existence through weapons of destruction, and caused irreparable damage to the environment that sustained you!'

II. CONCEPT AND FRAMEWORK OF TECHNOLOGY

In the study of technology of a culture in a defined period, some factors need to be kept in mind: (1) the relationship of technology with the environment, whether it is compatible with it or in conflict with it, and the nature of technological activities that are likely to endanger the environment; (2) the structure and size of the social organization which is supporting the technology and is responsible for using its products; (3) the type of raw materials used, whether they are renewable or non-renewable, and the extent to which they are exploited; (4) the type and source of energy used and the quantum of energy required or consumed to operate the technology; (5) the degree of specialization of operations in a technological system; (6) the relationship of technological operations with other activities, intellectual or otherwise, which are carried out in the society; and (7) the degree of diffusion of technological knowledge into the different strata of society.

In addition, four more factors need to be taken into consideration. Firstly, the culture which may condition or motivate the technological developments and fuel the hopes, aspirations and vision of the society. Secondly, is the inflow of technological knowledge from other culture areas being acquired by alluring those who possess the technological knowledge? Thirdly, is the system through which changes, improvements and developments take place in the technology through trial and error, improvements in practice, or input of new scientific knowledge (including the system by which the knowledge input takes place)? Lastly, the regional and climatic factors which might affect the development of technology must be identified.

For instance, a society located around a river will build an irrigation system, or one in a rain-fed area will build tanks for the same purpose; such a society may regard as backward those societies which have grown in an arid climate for not having an irrigation system. The societies in arid areas may have developed plants that suit their climatic and environmental conditions, and may be considered advanced in this respect. Similarly, those living in arid climates may use underground water resources, through underground water channels, natural or artificial, as in central Asia, and they may consider themselves more advanced than those who use open channels where water loss is greater.

The point which emerges, from these indicative examples, is that the development (or non-development) of a technology needs to be examined in the context of natural environment and the way humans shape the conditions of their existence. Nomads and nomadic tribes may also develop agriculture, though only marginally if at all, but they may be better suited to develop the necessary technology for rapid movement. As we know, nomads not only domesticated the horse but also developed the harness for this purpose. And once they developed this line along with armoury, as the Mongolians did, it enabled them to conquer vast lands and associated resources for their own use. Tribal organization provided them with the necessary cohesive grouping for these purposes.

Any upscaling of small works, whether in irrigation, architecture or the expertise of artisans and craftsmen, requires the necessary management technology to handle large-scale operations involving a large number of men and vast quantities of materials. This applied to ancient civilizations as well as to the medieval ones. Social organization and management are key factors in development, no less important than the technological ones. None of the examples of human achievements in different societies, mentioned earlier, would have been possible without management and administrative capacities developed in those societies to manage men and materials, on the one hand, and on the other the surpluses generated by the development of agriculture. Further, the management of men after the agricultural revolution was generally achieved through religious systems. This was essentially, to use modern terminology, social engineering. How effective these systems were can be seen from their continuance, in one form or another even to this day.[1]

Immigration of Carriers of Technology

A new factor in the development and diffusion of technology was the immigration of artisans and craftsmen. There were many causes for immigration; for instance, persecutions forced many craftsman to seek refuge elsewhere, as happened in central and west Asia after the Mongol invasion when a large number of artisans and craftsmen sought refuge in India. In India itself, the establishment of the Sultanate and of the kingdom in Gujarat and the Bahmani kingdom in the south led to large-scale migration of artisans and craftsmen, attracted by the encouragement and patronage offered by the new kingdoms which offered large incentives to master artisans and craftsmen to settle there and produce artifacts for them and perhaps also train others. Often the fall of a kingdom would also lead to migration from one kingdom to another.

This process of migration had two major impacts. Firstly, there occurred a diffusion of technology from one area to another. For example, the Chinese prisoners brought to Samarqand started making paper for the central Asian kingdoms. From Samarqand, the paper technology was brought to Sind in the tenth century and later to Kashmir under the patronage of King Zainul Abedin, from where it spread to all over India.

The second impact was connected with innovation. When immigrant craftsmen interacted with local artisans and craftsmen, it led to innovation in machinery, for example in textile manufacture, or in process, as in the case of transfer of block printing in textiles to book printing by the Chinese, thus improving the quality of the product.

Another factor responsible for the spread of arts and crafts within a country was the social mobility of workers from a low status to higher position in society. There may have been changes in social structure, either due to foreign conquests bringing forth new social ideas or due to reform movements. Such changes released the social energy of artisans and craftsmen, providing an impetus to new developments in technology.

The process of diffusion of scientific knowledge is different from the process of diffusion of technology. The former is either through oral discourse or through the written text, which may lead to different interpretations by different proponents. In the case of technology it is through demonstration. The immigrant craftsmen and local craftsmen working together may demonstrate the working of a machine, a process, or the making and quality of the product. Working together also erases social inequality as between higher and lower castes. This happened in the *karkhanas* of the kings and nobles, where hundreds or thousands of artisans and craftsmen worked together. The master craftsmen had apprentices who not only learned the fabrication and operation of simple machines, but also the product manufacture by watching or assisting the master. Working together also brought forth new design ideas to modify the machine to improve the product. Consequently, all the changes were within the prevailing framework and were thus incremental. Therefore a number of changes might have brought about a major change in a simple machine by increasing its efficiency or improving the quality of the product. In operating a machine, or using a process, a workman also increases his own skill in operating the machine, or in the use of a process improves the quality of the product. In India, due to lack of innovation in machinery, the emphasis was more on developing skill in operations to improving the product quality.

Further, the application of technique from one area to another (e.g. block printing in textiles to book printing) may lead to a major innovation. Similarly, the manufacture of a product in one country may stimulate interest in another for a more effective or an entirely different product. For example, the manufacture of hand-guns in Europe led to the fabrication of canons or the use of gunpowder in making rockets in India. This is, however, possible only when the necessary technical expertise is available in a country. Another factor which affects such a development is the culture of the people. A culture may inhibit innovation, perhaps by ignoring a major technical development of another country, as was evident from the example of the printing press and the clock brought to India by the Portuguese at the time of Jehangir. These significant technologies were then ignored since they were not needed or perhaps did not fit into the existing framework of culture.

Major innovations in technology can only take place when the technical knowledge is well developed, in a theoretical framework, and is applied to improve or change the technology. It is detrimental to both society and science when the available scientific knowledge is divorced from technology, or when there is no interaction between scientists and technologists or artisans and craftsmen due to social or other factors.

Technology Concept and Framework in India

The concept of culture area, as indicated in an earlier chapter, is more evident in the context of technology. There had been movements of artisans and craftsmen from India to other areas in Asia, and vice versa, in search of patronage or seeking refuge from invaders. With the establishment of Sultanates in Delhi, there was an increased inflow of artisans and craftsmen. The sack of Baghdad led to a large number of scientists, artisans and craftsmen taking refuge in India.[2] They also brought with them new ideas, designs and technologies in a number of areas.

The *karkhanas* established by the kings in the Sultanate period brought together a large number of artisans and craftsmen, both immigrant and local. This not only led to diffusion of technology but also promoted social mobility, as master artisans and craftsmen were highly prized. Firoze Shah (1351-88) had, for instance, established 36 *karkhanas*.[3] Mohammed bin Tughlaq (1325-51); according to Siddiqui, employed 4,000 workers in his *karkhanas*. When he shifted his capital to Daulatabad, he established *karkhanas* and other institutions as well.[4] This shifting might have also resulted in the movement of artisans and craftsmen, leading to further diffusion of technology and creation of new production centres for various products. The process might have been further strengthened with the establishment of local kingdoms. The nobles in the court of Delhi, copying the Sultan, also patronized artisans and craftsmen and vied with each other in drafting the better ones. In addition, the establishment of kingdoms in other parts of India (e.g. Gujarat, Gulbarga, Ahmadnagar and Golconda) and their efforts to attract and patronize artisans and masons, stone cutters, iron smiths, sarrafs and other artisans and craftsmen gave considerable impetus to diffusion and spread of technology.

Technology Documents of the Period

The advent of paper technology made it possible to write a large number of books, covering a number of areas, like personal chronicles, accounts of the reign of kings and expositions on philosophy, science and technology. Indeed, the introduction of paper technology marked the first step in knowledge revolution. The next step—of book printing—did not take place in India for quite a long time. The Chinese and later the Europeans were responsible for undertaking this step in knowledge revolution by printing books.

As a result of availability of paper, numerous documents about technological processes and products became available. Thus information became available in historical chronicles of the period, memoirs of kings, and special manuscripts which described processes and provided illustrations and paintings depicting handling of various machines and making of various products.

What is surprising is the late development in this respect, especially because we find available to us in Egypt, pictorial representation of various processes both in buildings and in papyri. Was it due to the greater respect and position accorded to artisans and craftsmen in Egyptian society, as compared to other societies? Or was the gap in writing or depiction of technological processes in India, due to the low position and status of artisans and craftsmen? May be the belated appearance of literature and depiction of machines and processes in India indicated the realization of the importance of technical processes and the enhancement of the position of artisans and craftsmen?

Tarikh-i-Firoze Shahi, an account of the reign of Firoze Tughlaq, as well as the other chronicles of the periods of Mohammed bin Tughlaq, Alauddin Khilji and other kings of the Sultanate period not only present accounts of various social developments, administrative measures, promotion of learning, establishment of *madarsas,* hospitals and *karkhanas,* but also provide accounts of scientific and technical developments, especially of some of the significant ones.

Abul Fazl's *Ain-e-Akbari*[5] is a mine of information on technology and technological developments up to this period. Some of the information available in *Ain-e-Akbari* gives us an idea of:

(i) metallurgical processes, like those involved in the production of zinc, making of brass and bronze, and alloys of copper and lead, including the exact quantities of ingredients required for making on alloy;
(ii) some of the important mechanical developments and inventions of the period; and
(iii) a list of other products of the period, made in different regions of the country.

One important text of the period, which gives an idea of the agricultural and textile technology, was *Miftah-al-Fuzala.*[6] S.P. Verma[7] has carried out a detailed study of the paintings in this work, giving the details of technology. Ishrat Alam[8] has also made a detailed study of the textile technology depicted in the work.

Among the other texts, mention may be made of *Tuti Nama* (1580-85) Which gives an idea of the various tools used in the textile industry,[9] and *Anwar Sahaili* which provides details of various features of hand-guns.[10] Verma also mentions the sugar-press in the manuscript of *Shah Jehan Nama,* belt-drive in *Razm Nama* and its 1603 illustrations (1582-84) and the water-mill at Aurangabad.[11]

This was a new tradition introduced in India during the period, and provided a rich source of information on technological history and the development of new technologies and products. It also provided an insight into the new demands on technology and the cultural responses generated by the technological developments of the period.

III. DIFFUSION OF TECHNOLOGY

There were many dimensions to the diffusion of knowledge. Firstly, as mentioned earlier. it was the transfer of technology, brought in by the immigrants. Then followed its adoption and diffusion in different regions. It is necessary to emphasize here that any technology brought in from outside or which came with the immigrants could be adopted only when the necessary technological base already existed in the country and the people had the necessary skills. Further, the technologies which came with the immigrants fitted well into the social or cultural milieu of the country, as they were part of a similar culture area, and hence they easily diffused widely, from one region to another.

Siddiqui gives an interesting account of one such case of transfer and diffusion. Mohammed Begara, Sultan of Gujarat, had invited an expert from Khurasan to lay a garden for him. While the garden was being constructed and laid, a local worker by the name of Bailu watched it carefully and later mentioned to the Sultan that he could do the same. And he constructed a magnificent garden for the Sultan, for which the Sultan praised him.[12]

The second feature of the diffusion was the spread of a technology from meeting one purpose to another. Lime mortar, which was then used for lining wells and tanks,[13] was later used for the construction and plastering of buildings, and still later for purposes of *araish* (i.e. decoration by floral and other designs). The use of lime mortar had an advantage over stone buildings, which were heavy and more expensive. The use of lime mortar in south Golconda and Bijapur enabled the construction of a large and beautiful building at the madrasa of Mahmud Gawan called the Gol Gumbaz, which turned out to be a most significant achievement. The *araish* was probably developed at Jaipur, by improving the ingredients of lime mortar as also by using it for plastering the insides of buildings. Subsequently, imparting a smooth and shiny finish, with coloured decoration, was another stage in the development of *araish* during the Mughal period in India. This became possible because it was a cultural need of the kings and the nobles.

As regards book printing, India had developed printing of textiles by using carved wooden blocks, but did not extend the use of this technology for printing of books, which China was able to do.[14] This was all the more surprising, particularly in view of the establishment of a large number of madrasas, which increased the demand for books for the use of students. The need, however, continued to be met by students copying the books, or calligraphers doing it. Was it due to aesthetic reasons, of developing different styles of writing, or was it to limit the availability of knowledge to a smaller section of people?

Here is an interesting example of diffusion of technology from the elite group to the people lower down: *Tuzuk-i-Jehangiri* mentions[15] that when Mariam Zamani Begum (Jehangir's mother-in-law) was making rose water for use in the palace, a scum appeared on the surface. Finding that its smell was very good she called it *Itr-i-Jehangiri.* The present author, while working in the CSIR, had the opportunity of visiting village Hessian in Aligarh district, where the rose is cultivated and the essence of rose and other perfumes are prepared. On enquiry about the name of the distillation apparatus, one of the workers told him that it was called *Nur Jehan ka Bhabka* (i.e. the distillation apparatus of Nur Jehan)!

The example is interesting from three points of view. Firstly, the nature of discovery (i.e. through accident) and its adoption and later development. Secondly, the diffusion of the technology from the palace to the village. Lastly, the continuation of the practice from the early seventeenth century to the twentieth century. In fact, if a critical study of different arts and crafts is made, one may find the same pattern being repeated in many cases—that is, an accidental discovery or innovation, its diffusion to different levels and regions, and lastly the continuation of the adopted innovation through centuries.

The instance of *Itr-i-Jehangiri,* the mechanical inventions of Fathullah Shirazi,[16] the descriptions of technologies in medieval India[17] and the metallurgical processes and technologies in *Ain-e-Akbari*[18] all bring out a basic feature of technological developments in India: they were based on trial and error and improvement of practices, as the artisans and craftsmen could only make limited and incremental advances. This was due to the absence of theoretical development owing to the separation of scientists and scholars from artisans and craftsmen. The medieval scientist could not go beyond the four-element theory to understand the nature of substances and their different constituents. This was also due to the absence of institutionalization of empirical experiences into a research system for the development of technology. The input of scientific knowledge in to technological processes, and the application of scientific method to the study of technology—in the development of machinery, improvement of processes and the quality of the product—are critical in the development of technology. It was the absence of this factor in India which was responsible for limited development of technology, on the one hand, and an over-emphasis on the development of skills in artisans and craftsmen, on the other. A study of the development of technology in Europe, during the same period, and later in Japan, brings out clearly the importance of interaction of scientists with artisans and craftsmen. This did not take place in India due to social and cultural factors, such as the one's prejudice against working with one's hands.

There is a need to study in detail the available literature to know the nature of technological developments and their linkages with other areas of human activity in the context of the then prevailing social and cultural milieu.

Machines and Labour Force

A number of scholars have been astonished by the absence of labour-saving devices in India, even in areas where these were used in neighbouring countries.[19] Irfan Habib quotes Babur about the abundance of skilled workers: 'A good thing in Hindustan is that it had unnumbered and endless workers of every kind.' Babur also said: 'There is a fixed caste for every sort of work and for everything.'[20] The abundance of skilled labour, extreme specialization, and the marginal living of artisans with their minimum simple tools, have been suggested as factors responsible for non-development of machines in India.

Arnold Pacey, suggested that population pressures acted as a factor in promoting inventions.[21] He also mentioned that a growing labour force inhibited the use of machines.[22] According to Pacey, while the Islamic culture, China and the west were mechanically minded, in India and southern Asia relatively little use was made of machines.[23] He further said that in India, there was 'no report of machines with gears, pulleys, cams or cranks before 1200'.[24] A very interesting dimension of Omar Khayyam's poetry, often missed by his translators, was brought out by Pacey—his imagery was based on Ptolemaic system and the mechanical devices then current in the Islamic world.[25] The poetry written in Persian and later in Urdu (this author is not aware about Sanskrit poetry) do contain references to different sciences as in the verses of Amir Khusro and others. But references to technology are found later in the Urdu poetry of Ghalib and Hali, especially references to European technology and its development and introduction in India.

The question which arises is why did the mechanical ideas, along with the mechanical devices brought in by the immigrant scholars, artisans and craftsmen not become a base for further technological development? To probe into the factors which were responsible for this situation, one has to look beyond the factors of abundance of labour, available skills, and caste. To say so, does not mean that these had no role to play, but to suggest that there were other factors also which need to be examined.

During this period, a number of new mechanical and other devices were introduced or developed, but they remained items of individual enterprise rather than a part of a single framework of a new method of thinking, as developed in the west. In Europe, the machines were developed not only to replace labour and to upgrade methods of production, but they also came to represent the working and processes of nature. The clock was not only a means of measuring time but it was also a symbol of cosmic order.[26] In contrast to this development in the west, in India the organic view of nature continued to dominate. The natural forces represented God's will (as in Islamic view) or an interplay of different gods (the Hindu view).

The sub-systems of nature were also organic—that is, the whole nature, with its sub-systems of animal and plant world, the mountains with their hidden treasures, the deserts, the rivers and the valleys were imbued with animistic spirits. In such a world-view machines could not represent a new vision of nature. Individual machines could be adopted or developed to meet a technical need, but that was all. It could not lead to a new way of thinking.

Further, in the religious systems prevalent in India, whether Hindu, Buddhist, Jain or Islamic, salvation was individual. Each individual had to find a way to work for *moksha* or *nijat*. This emphasis on individual effort might have had its influence on technology, in the development of individual skill rather than development of and reliance on machines to make refined and sophisticated products. Further, since the diffusion of these skills to a larger number of workers met the need for larger production, mechanical inventiveness was further inhibited.

The point being emphasized is that the cosmological view of nature combined with the religious views and beliefs with their emphasis on the individual might also have played a role in the development and nature of technology.

Today, with the development of science, when the knowledge of natural environment is in continuous interaction with social environment, and the mechanical view of nature and the ideas of technological progress is under review and change, it is necessary to critically examine the cosmological view of nature in relation to technical processes. India during the period from the tenth to the eighteenth centuries was mostly using natural renewable resources, with the exception of the armament industry. These resources were used to meet human needs and sustain the social system. Simple tools and mechanical devices produced most sophisticated products of high quality, with beautiful designs, as well as products to meet the needs of the common man. Religious beliefs and values imposed a certain degree of self-discipline with regard to the use of materials and meeting of individual needs for a larger number of people, barring a few.

Looking at the features of the society which created the emphasis on use of human labour in preference to development of machines, it may be pointed out that the concept of labour saving and also the use of some related equipment was already there. The use of such equipment as crank, block printing in textiles, water-wheel and water-mill does indicate that they were invented and used. In this context, three innovations of Fathullah Shirazi[27]—namely, the gun-cleaning machine, the multi-barrelled cannon and the wagon-mill—were certainly labour saving devices. Whether they were merely curios to demonstrate the ingenuity of the inventor or were actually used or not is besides the point. The point is that a need was felt and there was the necessary technological skill and capacity to fulfil it. What needs to be studied is, why this concept did not catch on and why no further development in this direction took place. This requires to be examined in the context of social and cultural features of the society. It will be worthwhile to briefly look into these aspects.

In this context, two sets of features of these societies need to be mentioned. Firstly, there was considerable diffusion of knowledge and technology in a manner that prompted every household in rural areas and most in the urban centres to meet their own needs in terms of making of cloth and its dying and printing; making of food preserves like pickles, sugared fruits and *sherbets*; making of cosmetics like perfumed oils and rose water; distillation of various herbal extracts; and making of medicines and dietary supplements for different seasons and conditions of health. These activities were part of the daily chores of the households which of course varied in different seasons depending on the availability of the materials. The *karkhanas* or small-scale production units were also to meet the needs of the kings, the nobility, the rich land-holders and the traders.

The second set of features covered three areas: factors affecting the growth of population, the concept of austerity, and the concept of stable society. Firstly, despite the abundance of natural resources, the demand on them was limited due to limited growth in population. Three main factors were operational here: (a) large mortality rate at childbirth; (b) large-scale mortality due to epidemics and occasional famines; and (c) large casualties in wars, which were almost continuous.

Secondly, the prevalent religious systems—Hinduism, Jainism, Buddhism, Islam and others—preached a code of conduct for the use of materials and introduced the concepts of limiting one's needs and practicing austerity as a virtue. Though the kings and nobles lived a luxurious life, with lavishness and waste being the major features, the vast masses were imbued with a philosophy of austerity. This greatly limited the demand on natural resources.

Thirdly, the concept of society in this period was, unlike the present concept of unending development with unending demand on natural resources, one of creating a stable society and a production system that suited this objective. Though empires rose and fell and changes were brought about by religion and conquests by foreigners, the social and productive systems, based as they were on agriculture and an industry dependent on the use of renewable resources, remained by and large unaffected.

In view of these features of the society, all that was needed was the availability of a large number of skilled workers to meet the demands of people's daily needs as well as the needs of the kings and nobility for more sophisticated products. The medieval society was thus a divided society in terms of demands for products. The kings and the nobles living in affluence required highly sophisticated and expensive products, while the rest of the people appeared to be satisfied with simple products, to meet their daily needs. The artisans and craftsmen used the same simple tools to meet both the requirements. It was the skill and the mastery of the process that mattered.

The depletion of non-renewable resources, the pollution caused by technological processes, and the damage to the natural environment and ecological systems, has been considerable. This necessitates the need to minimize pollution, slow down depletion of resources and create a trend to develop and use renewable resources. Therefore, a critical look at the developments in India from the tenth to the eighteenth century becomes necessary.

IV. NATURE AND CHARACTER OF TECHNOLOGY

In the brief and indicative description which follows, the objective is not to give details of the various technologies developed, but to indicate the capacities developed in different areas of technology, the system of operations of different technologies, and the linkages between various technologies. For instance, the close linkage of medicinal and food systems with agriculture, of processing with manufacturing technology, between the dual needs of the elite and the common people, of textile with dye industry, and of all these with astronomy. Further, we should examine the methods and techniques developed, the motivations for developing a particular technology for making a particular product and the purpose for which it was made.

The European accounts of the historical development of technology are centred around the two concepts of utility and efficiency in production, on the one hand, and the linkages with the knowledge system, on the other. These concepts are not applicable to the development of technology in India, because the technological developments here were essentially aimed at meeting the needs and fancies of the kings and nobles, who patronized the master craftsmen. The objective was to excel in what their predecessors had achieved or their contemporaries were capable of achieving, to leave behind their name and fame in history. Since quite a few of the products were meant for kings and nobility, these products reflected their sensitivities and aesthetic values, in terms of elaborate designs, patterns of inlay work and carvings.

In terms of motivation, therefore, the productive resources and capacities were directed towards this end, rather than for further development of resources and systems of production.

Here, note should also be taken of the prevailing concept of development of society. As mentioned earlier, the concept which was prevalent throughout this period appeared to be one of a stable society, built around agriculture, and a social organization which could survive with marginal damage despite wars, differences of religions, philosophies and other approaches to the process of living.

In the context of technology, two features are significant, which sharply contrast with the contemporary technological development. Firstly, there was an effort to live in symbiotic relationship with the environment and to meet day-to-day requirements as a means of survival. Secondly, which is most important, perhaps a conscious effort was made to provide individuals and communities with skills to do and make things for themselves. It was this ability which enabled people not to depend on outside sources. The skills which were available and developed, both in the villages and the urban centres, could meet a whole range of the people's needs to make life contented as well as aesthetic.

The motor for change here was not technology, which was the dominant factor after the industrial revolution in Europe; it continued to be the human beings with skills as their survival kit. Consequently, all the movements for reform and change in society during this period were directed towards providing moral and social philosophies to humans, combined with developments for the uplift of the downtrodden, resulting in their social mobility and releasing of social energies for technological developments that took place.

The descriptions of a few technologies which follow are aimed at reflecting these dimensions. Accordingly, instead of following the established practice of describing technologies sector-wise or subject-wise, the author proposes to describe them under the following categories:

(i) demonstrative technology
(ii) construction technology
(iii) technology of materials/products of everyday use
(iv) metal technology

Demonstrative Technology

There are a large number of items which have been available since antiquity as a reminder of technological capabilities in the country, though their utility might have been limited. Take, for instance, the iron pillar in Delhi at the Qutab complex. It is a reminder of the degree to which ferrous technology was developed. In the same manner, the ancient stone cutters demonstrated their skill through the pillar now at Firoze Shah Kotla, Delhi, both in making such a tall stone pillar and in polishing it to such a high degree. In the same tradition, the builders and stone cutters demonstrated their skill in erecting the Qutab Minar. Here, the new addition to their repertoire was the calligraphic skill, which adorns the minar.

In the same tradition were the mechanical contrivances of Fathullah Shirazi, who demonstrated both metallurgical capabilities and engineering skill, along with his inventive capacity in constructing the gun-cleaning machine, the multi-barrelled cannon, the wagon-mill and the travelling bath. These models effectively demonstrate the technological capabilities which existed in India.

Just as the iron pillar demonstrated metallurgical and casting capabilities, so did the cannon Malik Maidan at Golconda. Its utility was obviously limited, one wonders if it was ever used, yet it is a reminder of the skills and capabilities which then existed.

The knowledge of metallurgical and casting skills are most important in the casting of various gods and goddesses with different metals or a mixture of metals and alloys, in different postures and with a high degree of artistic refinement. The factors that could be discerned in their making are not only religious beliefs but also metallurgical knowledge and skills and artistic and aesthetic sensibilities. Over the years one could see the evolution and refinement according to the prevalent cultural ethos. The same refinements are evident in the making of temple bells.

What was being achieved by metallurgists and casters (smiths) was also demonstrated by masons and stone-cutters, as if they were competing with each other: if you can do it we can do it better. The statues of Buddha in different postures and of Mahavira, particularly at Shravan Belagola, demonstrate the high degree of skill reached by the stone-cutters.

These and many more examples were, in a sense, demonstrative models reflecting the knowledge of materials, skills achieved and the aesthetic and artistic sensitivities developed. The question arises as to why this knowledge and expertise, particularly those demonstrated in the contrivances of Fathullah Shirazi, were not utilized in developing better tools and machines for the workmen to improve their production efficiency?

Irfan Habib and others[28] have suggested two factors—poverty of artisans and craftsmen, and the consequent inability to invest in the improvement of tools, and abundance of skilled labour. These factors were important, but then there were also a large number of *karkhanas* organized by the kings, which could easily invest in developing machines to promote production. In addition to these factors therefore, there is a need to look into religious and cultural factors as discussed earlier.

There is a need to go more critically into literature to throw light on this aspect, to discover why a people, otherwise highly alert and intelligent, who could organize a sophisticated administrative and financial system, and also develop *karkhanas*, could not give a push to production technology, and remained contented with merely demonstrative models.

Construction Technology

Every king during his reign wanted his fame to spread as far as possible, and his reign to be remembered forever. Reminders of a king's fame and name and the prosperity of the period were invariably left behind in architectural remains. Three types of structures were attempted—palaces, places of worship, and mausoleums.

The palaces were built inside forts to provide safety to the kings. Forts were massive structures, built of heavy and large stones, with a number of walls to provide safety to the inmates. Forts like those of Daulatabad, Golconda, Sirifort, and Tughlaqabad were considered non-conquerable. Inside these forts, palaces were built for kings and nobles and their entourage. The transformation in fort-palace complexes took place with the construction of forts at Agra and Fatehpur Sikri, followed by the Red Fort in Delhi. In all these forts heavy stone walls are replaced by red sandstone as surfacing material, giving them a new elegance. The palaces inside these forts were also more elegant and elaborate to meet the needs of various state functions. The complexes included *Diwan-e-Khas*, *Diwan-e-Aam*, place of worship, and various living chambers for the king, his harem, dependents, etc. There were elaborate carvings, water channels, fountains and gardens.

The construction of gardens with their elaborate layout, fountains and channels of running water was a major feature of the architecture, both of palaces and mausoleums. Apart from having fruit trees, the gardens were also designed to suit the climate and the seasons. During winter, since a part of the day was spent in the garden, there were grown colourful flowers, blooming during the day. During summer, they spent the evenings in the garden. To enhance the beauty of the evening, sweet scented plants were planted which made the garden radiate beautiful smells into the surroundings. This was indicative of the rich resources then available, elegant style of living, and lessened concern for security. Perhaps the later kings learnt the lesson that the massive forts were conquered more by betrayal than by army assaults; and they depended more on the organization and loyalty of the army, by keeping it satisfied, than on mere fortification. They were also reflective of prosperity, as a result of surplus agricultural production.

Another development in this context was the use of lime plastering inside palaces, with elaborate paintings of various motifs. This development was common in both north and south, as would be evident from the pavilion in Hampi. This is interesting in view of abundance of stone in south.

It may be worthwhile to make a comparative study of a few forts like Gaur in the east, Champaner in the west, Tughlaqabad and Red Fort in Delhi, Daulatabad, Hampi and Golconda in the south. This comparison may be made from the points of view of architecture, use of materials, possible costs and effectiveness and the period of use, on the one hand, and the organization of palaces and the like in them and the life styles developed, on the other.

The second area of construction technology to commemorate the commitment of kings to their religious faith was the building of places of worship. The construction of these places, in terms of materials used, depended on the region and the faith of the worshippers. The Hindu, Buddhist and Jain temples had similarities as well as differences. In these religions, gods and goddesses were worshipped individually. Therefore, the inner sanctum sanctorum was made small for an individual to offer his/her obeisance and have the *darshan*. A large courtyard allowed for the assembly of a large number of people and for cultural activities like dance and singing. The Buddhist worship, though individual, required stupas with large halls and a large complex of individual chambers. In east India, baked tiles were used for constructing stupas, as stone was not easily available. The other constructions used lime plaster on baked bricks to give it some longevity. One characteristic feature of temple complexes was adorning the walls with beautiful sculptures representing both religious motifs and the science of everyday life. In temples where lime plaster was used on inside walls, elaborate paintings were made.

The Muslim places of worship were different in character due to the communal and congregational nature of worship. These were mostly stone structures. However, over a period of time they underwent a major evolution in terms of construction. The early masons were probably non-Muslims or converts, and they did not fully understand the nature of worship, so that many of the mosques had niches which suggested 1+1+1..., as if each individual offered prayer individually; only the later mosques had sweep merging the individuality into communal worship. Further, early mosques did not have domes which later became a major feature of mosques along with the minarets. One of the main features of mosques in India, in contrast to those elsewhere, was that they had two minarets, instead of one, perhaps guided by the desire to have symmetry. The concept of symmetry was highly developed: if a line was drawn in the centre of a mosque, as in other constructions, the two halves would be the exact replicas of each other. In contrast to the temples, the mosques did not have any elaborate decorations with the exception of calligraphy from the *Quran*, so as not to distract the attention of the worshippers from paying their obeisance to a formless and abstract concept of God.

Mausoleums were essentially Muslims constructs as the Muslim buried their dead. Later, in some places, the Hindus (e.g. in Rajasthan) began to construct elaborate *chattaries* to commemorate the dead.

In the construction of mausoleums, mostly of kings and nobles, one finds a set pattern—a central structure with a dome, where the grave was, surrounded by a garden and then a boundary wall. Many mausoleums had mosques attached to them and often a *madrasa* for teaching purposes. The evolution of mausoleums follows the same pattern, described earlier:

that is, in the beginning they were heavy stone structures with wide walls to support a heavy dome. Later on, the construction was made more refined, with stone being used as surfacing material. This allowed the possibility of using carved stones with inlay work, both of floral patterns and calligraphic portions from the *Quran*. The best examples of the latter are the tomb of Etamaduddaulah and the Taj Mahal at Agra. This was in sharp contrast to mosques where no embellishments were made. One of the problems faced by the architects was connected with the dome, which had to be of proper size to match the supporting structure below. In other words, they appeared to transform a geometrical problem into a piece of architecture, the area of the circumference of the dome being equal to the square below. Humayun's tomb in Delhi is a beautiful example of this effort.

As a part of construction technology two types of capabilities were developed to a very high degree, namely, stone cutting and inlay work. In the former, when the stone was being used as surfacing material, the size of the stone being cut for the construction of domes and minarets needed to be worked out as a number of various sizes were needed to achieve the geometrical designs of the building.

The inlay work required different types of highly acquired skills, more elaborate and sophisticated when calligraphy was used. The understanding of optics was necessary to avoid parallax error. This can be seen in the Taj Mahal. Another skill lay in making delicate patterns of different types of grilles, single or double, the latter as in Fatehpur Sikri. The most beautiful grilles representing a high degree of symmetry could be seen at the mosque in Ahmedabad. All these examples exhibit the integration of the knowledge of optics and geometry into acquired skills. There is no evidence in available literature, of any architectural designs, scale drawings or models having been made. According to Pacey,[29] in the construction of Taj Mahal, models were made and used for the purpose of construction. If that was so then in all probability, scale drawings and models were also used for construction, particularly of mosques and mausoleums. This might have been a Mughal period development. The available evidence indicates that most of the architects were accomplished mathematicians and were well-versed in geometry. The account of one family, that of Ustad Ahmad Almi'mar Lahori, indicates their accomplishment in mathematics. They apart from writing their own books, also translated mathematical texts from Sanskrit. The grandson of Ustad Ahmad who had constructed the mausoleum of Rabi Durrani, the wife of Aurangzeb, was an accomplished mathematician and had translated a number of Sanskrit books on science into Persian.

In contrast to the mausoleum of kings, the mausoleums of Sufi saints—the Dargahs—represented an altogether different pattern: in their construction they resembled the temple minus the *gopuram* and the sculpture. There was a small enclosure with a screen surrounding the grave, where everyone individually made his/her obeisance, in sharp contrast to a mosque where praying was communal; here, the idol was replaced by the grave. The quadrangle outside was organized for visitors who came to the Dargah and whose devotional songs were recited on various religious occasions or otherwise.

The two areas of technology, which have been briefly discussed above, clearly indicate that there was no concept of technological development. The kings and nobles only wanted to use the existing technological capabilities for producing distinctive objects for people to admire or for constructing buildings for which they would be remembered for generations to come. In doing so, they patronized the master craftsmen, honoured them and provided them with facilities to make incremental changes, to excel so that their final products were better than any made earlier. The question of their utility and efficiency, at least in the two areas discussed, did not appear to have entered in the technological system.

The second feature of the construct was the high degree of knowledge of materials by master craftsmen and builders and the improvements they brought about in the professional practices to make the final product highly sophisticated and beautiful. But the idea of replicating those products on a large scale did not arise, because every object had to be unique. Lastly, another feature of the constructions erected was that they reflected the aesthetics of the period and represented a high degree of quality to attract attention and elicit admiration.

Technology of Materials and Products of Everyday Use

India during the period excelled in technologies which were connected with products of everyday use. These products were made from either agricultural or forest produce. The system of production was mostly decentralized, with each household making for itself, using low energy, mostly depending on solar energy.

Though there were people specializing in making herbal medicines—making distillation products, herbal extracts and oxides of metals—a number of households made their own preparations. Along with it went the preparation of foods for different conditions of health and sickness. Pickles, *murabbas* (sugared fruits), *chutneys* and fermented products were made for preserving produce for off-season use as well as for dietary purposes. The making of sherbets, extraction of essential oils, preparation of perfumed oils and extraction of such herbs as mint were common. Aniseed was preserved for use in different seasons and conditions of health. Different diets, various types of perfumed oils, perfumes and herbal products were integrated with medical theory, the seasons and climatic factors.

Connected with agriculture and orchards, which were planted on a large scale, by both kings and nobles, was the development of grafting technology and production of different fruits, developed for their sweetness, flavour and aroma, consistency and hardness or softness of the pulp, for making products available in off-seasons. Jehangir, for instance, mentions the availability of mango in off-season developed by one of his nobles.[30]

There was considerable variation in the practice of making products in different regions of the country, depending on the type of products and the taste of the people. Apart from taste, climatic factors, seasonal variations and keeping quality of the products also affected the practice. In addition certain people, either for religious reasons or for matter of taste, avoided the use of certain materials, and this also had an effect on regional products.[31]

Amongst the products made were the cosmetics, in particular a variety of perfume, used by the kings and nobility. The *Ain-e-Akbari* gives a long list of perfumes which were being made in India during Akbar's time.[32] The description provided gives details for recognizing the material, different varieties, their Persian and Indian names, and methods of preparation.

An interesting feature of the description is that it gives a list of flowers and other materials, indigenous to India, for making perfumes using methods which were long known and practiced in India. The point which should be taken note of is that, inspite of the spread of the empire covering different regions of the country, there was considerable diffusion of practices from one region to another.

One of the interesting areas of technological development was the press, made of stone, for extraction of oil, to begin with. Dr Achaya has brought out a detailed study of the traditional oil mills in India.[33] It brings out the nature of equipment and practices employed and the quantity and quality produced in different regions of India. It was, according to Achaya, a bullock-drawn device based on mortar-and-pestle system to press oil out of oil seeds. The device was 'repeatedly alluded to in the *Rig Veda* of 1500 BC ... This appears to have given rise to an oil seed crushing appliance of some kind, and by 500 BC oil mills were well established ...'[34]

A different type of press-mill, in contrast to the oil-press, appears to have been developed for extraction of juice from sugarcane. We are not aware as to where exactly it originated, whether in India or outside. The earliest record of it is found in *Shah Jehan Nama* (1657).[35]

The device had two wooden rollers, with crankshaft to move them so as to press the cane. According to Verma, the pestle-and-mortar sugar press co-existed in India with this press based on parallel worm (vertically mounted wooden rollers), which was recorded in the seventeenth century.[36] However, like the *ghani*, a detailed study of regional differences in equipment and practices in this area is required to be made.

The textile technology was highly developed in all aspects, from production of cotton fibre to manufacture of textiles and their dyeing and printing. Ishrat Alam, in a detailed study of textile tools, described the cotton-gin used for separating seeds from cotton fibre, first depicted in Ajanta paintings.[37] He also asserted that worm-rollers used in the cotton-gin and the sugar-press were indigenous to India. According to him, the crank-handle was a later device, the documentary evidence of which could be found in *Bahar-i-Ajam* (1740) and in Kangra paintings of the eighteenth century.[38] The bow-string device for opening the knots and loosening the fibre was depicted in Mughal paintings of the sixteenth century, though its origin might go back to the ancient period. The spinning-wheel, according to Alam, was introduced in India during the Ghorian period (thirteenth-fourteenth century), along with the belt-device to speed it up for the yarn to be wound around it. For the purpose of dyeing before being woven, the yarn was made into coils on the spinning wheel.[39] The weaving was done on a loom.

A large variety of cloth was woven, from simple to highly refined and sophisticated, including cloth with silver and gold threads. Also, a wide variety of colours were used, mostly of vegetable origin. The dyeing technique was highly developed, from tie-and-dye method to block printing, including the use of mordents.

Apart from textile technology, another area connected with it was the development of dress designs. New patterns and designs were developed, for daily use, depending on the seasons and the ceremonial occasions. The style underwent many changes during this period, both for ladies' wear and men's wear. The luxuriousness of the apparel depended on the status of the person concerned. There was also regional variation besides variation between dresses for Hindus and Muslims. This is evident from a few dresses now on display in different museums. Noor Jehan was said to have had a major hand in developing dress designs by introducing designs incorporating Iranian and Indian designs. This is another area which requires to be studied in some detail.

Apart from textiles, other items which were made using simple textile tools like the loom were carpets. These were made of cotton and silk as well as wool. The technology in all probability came from outside, but took root in India, in particular in Kashmir, established and promoted by Sultan Zainul Abedin. Mention may also be made here of mats made of grass and reeds. Mats had beautiful designs as well as coloured patterns.

Another area of technological development was that of utensils. A large variety of materials were used for this purpose. Copper vessels with *kalai* (tinning) were extensively used for cooking purposes. Some of these were very large, designed to cook for a large number of people connected with the households of kings and nobles. The size of some of the utensils were enormous, like the two *degs* at the *Durgah* at Ajmer, still used for cooking in the langar. This is illustrative of the technological capability for making such large size vessels. Similar large iron pans were made both for cooking purposes and for making other products. However, most of the common people used unglazed or occasionally glazed earthenware for cooking.

For fetching and storing water brass or earthenware were used. Trays, plates and cups were made with highly glazed surfaces in delicate colours and patterns. The kings and nobles also used gold, silver and jade plates and cups for eating and drinking. These like ceramic utensils had intricate engravings or designs of written text and floral patterns. The common people mostly used unglazed and often glazed earthenware. Baked tiles and ceramic coloured tiles were also made for purposes of decoration. Other utensils used were made of wood, including cups (*piyalas*) and plates. These were also made of bamboo. Wooden utensils were often coated. This indicates that a number of different materials were used for making objects for daily use. The elegance and beauty of the objects reflected not only the knowledge of materials and the technologies used for making the products but also the aesthetics of the period. However, the technology was developed through experience and the skills were acquired over a period of time, and was passed on from one generation to another, through a system of apprenticeship.

Metal Technology

Apart from agriculture, around which a number of technologies were developed, an other important area was connected with metal technology. This area can be sub-divided into:

1. armament technology
2. coinage technology and
3. technology of jewellery and other artifacts.

Armament Technology: Apart from agriculture, war was a major preoccupation in the medieval period. It was one of the means of acquiring or generating resources, through the capture of other territories. Unfortunately, so far no study has been made to find out if wars consumed more resources than the gains made by capturing and occupying more territory.

Armies had to be equipped with weapons—arrows, swords, shields, armour, guns, cannons and rockets. The necessary industries and *karkhanas* for the manufacture of these items had to be established. And to keep these *karkhanas* going, proper mechanism had to created and managed for mining and smelting operations and for supply of raw materials for manufacture of weapons. Considering the size of the armies of various kingdoms in north, south, east and west, even those of small rajas and nawabs, the demand for iron must have been considerable for making the various items and manufacturing steel.

The mines were all over India. Jafar Mahmud had listed 19 mining sites in different parts of India,[40] and the type of ore available at each site. The mining was done by both open-cast mining and shaft mining using simple tools.

Smelting was carried out in furnaces, and according to Jafar Mahmud, though they appeared crude in appearance, they were fabricated with precision using the middle finger and arm length as the standard of measurement, with the ratio of 6:5 being maintained throughout.[41] The furnaces were ringed by bellows or air channels, and the air blast entered the furnace containing coal and smelting material. Percey[42] has given the details of making steel and wootz steel and according to him, the smelt composition had high carbon content, which gave the iron its special quality of hardness.

The iron was used to make gun barrels of different varieties; according to Jafar Mahmud, these were called plain, *pechdar* or *johardar*,[43] the differences being in the number of rods required for making them and the manner of manufacture.

Ain-e-Akbari gives details of gun-making.[44] The description provides an insight into the problems of making guns and the possible defects, owing to which the barrel would often burst. A study of details also gives an idea of the trial-and-error method of making and removing the defects. These defects were quite evident when this description is compared with that given in *Babur Nama*.[45] The latter shows that the success of each effort depended on the calculations relating to the material composition and the furnaces. The two descriptions also give an idea of the improvements made since Babur's time.

The barrels of the guns and cannons, if made for kings and nobles, were engraved with gold, silver or enamelled with calligraphy, wherever required.[46]

During Akbar's period a major change took place in the material used for casting cannons. This was due to the standardization of the production method of brass, details of which were given in *Ain-e-Akbari*. As a result of this development cannons were cast in brass in preference to bronze. The brass cannons were small compared to the iron ones. The cannon at Bishnupur, probably cast in the same period, appears to have been made by the method given in *Ain-e-Akbari*.

There appears to have been considerable experimentation, through trial and error, in making guns and cannons, to meet different sets of requirements. In this context, major problems were faced when large and heavy cannons were to be hauled over mountainous terrain, or were to be carried atop a cliff for stratagical advantage. An effort in this direction was made by Fathullah Shirazi, who made a 'screw cannon'. The idea appears to have been to haul the different pieces atop and assemble them there for use. *Ain-e-Akbari* provides a drawing of it.[47] Several pieces of them were made and moved where heavy artillery would not be useful. Another development in this area was the making of multi-barrel cannons, with as many as seventeen barrels. This cannon could be fired with one matchlock.[48]

Ain-e-Akbari also gives a list of 77 weapons used by the army along with their drawings.[49] This gives an idea of both the scale of arsenal and of the magnitude of production starting from the huge quantities of mined ores, their smelting to produce iron, and finally the fabrication of the weapons. This also indicates the high organizational and management systems that must have been achieved during the period. Since *Ain-e-Akbari* mentions that guns were made in royal *karkhanas* as well as purchased and presented,[50] it is obvious that there were numerous centres of production all over the country.

Ain-e-Akbari also gives drawings of different types of armour, with elaborate designs, engravings and other patterns; these obviously were meant for kings and nobles, and would have been made in small numbers compared to other weapons. The quantities of weapons produced, the amounts of materials consumed and the manufacturing capacities built up must have been enormous, since a number of kingdoms and a large number of nobles were to be catered for.

Like the gun and cannon technology, rocket technology was also imported into India, most probably brought in by the Mughals. In the list of armaments in the arsenal of Akbar, rocket was mentioned at the end.[51] However, the word for rocket, *ban*, suggests its Indian origin and it might have been used as part of fireworks in India. As already mentioned, Indians were aware of saltpetre, and this knowledge had influenced the Chinese recipe for gunpowder.[52]

Major developments in rocketry took place in the south, with Hyder Ali and Tipu Sultan having recognized the value of rockets as a military weapon. According to Dutta,[53] Tipu had sent rockets as presents to the Ottoman king, as they were not known in the Turkish Empire. According to the various accounts mentioned by Dutta, there were a variety of rockets, including ground rockets, and a large number of trained rocket-men could direct a rocket to strike a particular target.

Gunpowder was known in China since AD 900 and rockets were developed by the Chinese by AD 1150. Rockets may have followed the same route as the paper technology—from China to Islamic countries and from there to India, with the advent of the Mughals.

The question as to whether they were indigenous or came to India via central Asia requires to be looked into. However, with fluid borders and constant changes in the spread of empires and the immigration of people, there were inflows as well as outflows of technology, through various channels.

Coinage Technology: This area has been well-researched and considerable literature is available on the subject. B.N. Mukherji in a comprehensive paper has discussed the types of coins made in India since antiquity.[54] He mentions four types of coins: (i) archaic die struck; (ii) cast; (iii) repous; and (iv) die struck. The coins were made of copper, silver and gold.

There are two major accounts of processes of refining metals for making coins. Mukherji gives some idea of the processes described by Thakura Pheru, master of the mint of Alauddin Khilji.[55] The other detailed account is found in *Ain-e-Akbari*.[56] It describes the type of workmen employed and gives details of the processes of refining various metals for making coins. The processes are illustrated, showing workmen at different stages of work. The description also covers different types of coins, their weights, sizes and other details. A brief discussion on the origin of metals indicates the continuation of the four-element theory and their categorization.[57]

Two points need to be stressed here. Firstly, as already mentioned, Fathullah Shirazi in his effort to undertake currency reforms had weighed coins and noticed the loss of weight during the time of their circulation, and as such he might have developed some idea of statistics. Secondly, *Ain-e-Akbari* also mentions the specific gravities of different metals, explains the displacement of water by different metals, and describes the method of working out specific gravity.[58]

Jewellery: It will be worthwhile to very briefly mention jewellery as a major item of consumption of precious metals, its large-scale production, its production technology, and its role in art and culture.

Jewellery was a small-scale industry, with goldsmiths spread all over India, producing tailor-made articles for their clients. The technology covered the fine decorative designs and inlaying of precious stones, including cutting of precious stones and diamonds in different shapes and designs to suit specific ornaments. The ornaments covered a large variety of items, ranging from head-gear to items meant for different parts of the body down to the feet. Ornaments for men and women were different in design and purpose.

Three aspects were integrated into the manufacture of jewellery—technology, art and culture. Further, the items of jewellery were indicative of the affluence and status of the person wearing them.[59]

V. CONCLUDING REMARKS

The preceding discussion on technology was only indicative of some of the areas, and the type of technologies developed. It was neither comprehensive nor aimed at providing details. It was meant to highlight some of the features of technology of the period. In the first chapter the concept of culture area was discussed, which is particularly applicable in the case of technology.

Arnold Pacey has developed the concept of what he calls *technological dialogue*.[60] According to him, technological dialogue was inventive exchange of different technologies that took place between different regions of Asia. The major areas of exchange as mentioned by him were as follows:

India played a major role in textiles and in the propagation of crop plants, especially in spreading south Asian plants to the rest of the world. Persian empires made a major contribution to the technology of construction of dams, canals and irrigation works. Islamic civilizations played a major role in adopting ancient techniques to meet new demands in the area of mechanical devices, hydraulic technology and water-raising wheels, wind-mills, and corn-milling machines. China's contribution lay in the areas of porcelain, dyes, cotton weaving, silk manufacture, paper making and steel making.

The process by which the interaction between technologies and their diffusion took place, was the conquest of various areas to spread the boundaries of empires, which resulted in the capturing of artisans and craftsmen, their immigration, and trade, both by land and sea. Arab ships, by the middle of the eighteenth century, were sailing all over the Indian ocean and Chinese junks were visiting Indian ports.

The second point which Pacey stresses is that similar inventions appeared in different parts of the world, independently or through stimulation provided by one society to another. However, these developments were possible only when technological skills were available. He also stated:

> The kind of technology which any society develops must depend on its utility to mobilize labour for relevant skills, and to encourage innovation. Such capabilities depend in turn on the effectiveness of commercial, industrial and governmental institutions.[61]

Taking that into account India had during the period all the necessary institutions, yet the innovative process was not organized or fully developed.

During this period all the empires—the Ottoman, Persian, Mughal India and Chinese—were, as Pacey calls them, gunpowder empires. All of them had similar institutions covering military, court life and culture, with the exception of China which was run by professional administrators.[62] Further, Pacey points out three other features: firstly, these countries had single-culture technologies; secondly, guns were status symbols; and lastly, the acquisition and manufacture of guns required more resources and better administration, which only a large empire could provide.

The development of technology in India, apart from the techniques developed, has to be seen in this context. Further, it is not merely a question of having the necessary information, or the development of a technique or discovery but the development of a methodology for developing innovations and new technologies. India during the period was not able to develop the methodology of invention, which Europe was able to develop, by linking scientific knowledge with technologies and creating the necessary institutions to promote this process. This inability made for India's dependency, which was fully exploited by the colonial power. This feature was the outcome of the thwarting of knowledge revolution, which stopped at adopting paper technology, and refused to develop book printing. And as such, the unavailability of scientific knowledge to the craftsmen, on the one hand, and the inability of scientists to interact with artisans and craftsmen and provide answers to their problems, on the other, were the major hurdles in the development of the technological process in India.

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42. J. Percey, *Metallurgy: Iron and Steel*, London, vide Jafar Mahmud, p. 42.
43. *Ibid.*, p. 57.
44. *Ain-e-Akbari, loc. cit.*, pp. 119-23.
45. *Babur-Nama*, translated by A.S. Beverage, London, Luzac 1922, pp. 536-7.
46. *Ain-e-Akbari, loc. cit.*, p. 121.
47. M.A. Alvi and A. Rahman, *loc. cit.*
48. *Ibid.*
49. *Ain-e-Akbari*, pp. 117-19.
50. *Ibid.* p. 122.
51. *Ibid.*, p. 119.
52. Pacey, *loc. cit.*, p. 16.
53. P.K. Dutta, *Technology in Ancient and Medieval India*, ed., A Roy and S.K. Bagchi, p. 42.
54. Vide A. Roy and S.K. Bagchi, *loc. cit.*, pp. 47-70.
55. *Ibid.*, pp. 57-8.
56. *Ain-e-Akbari*, pp. 16-52.
57. *Ibid.*, pp. 19-43.
58. *Ibid.*, pp. 44-5.
59. I am not going into details, as the objective is to indicate the dimension of technology, often ignored. For designs and types of jewellery one could refer to Jamila Brij Bhushan's *Indian Jewellery: Ornaments and Decorative Designs*.
60. Pacey, *loc. cit.*, p. 15.
61. *Ibid.*, pp. 17-18.
62. *Ibid.*, p. 79.

CHAPTER X

Paper Technology in India

A. Rahman

I. PREAMBLE

Paper manufacturing and book printing marks the beginning of the knowledge revolution. The availability of paper allowed information and scientific knowledge to be written down and made accessible to a larger number of people, irrespective of caste or religion, that is, it cut across social barriers. In education, it permitted the shift from the oral tradition of cramming of text to studying the written text. It thus opened new ways of thinking and developing knowledge.

The availability of paper during the period marked the beginning of writing and printing of a large number of books, commentaries, information about technical practices, including drawings and paintings, giving information on natural history, technical processes and the equipment used. The availability of these books enabled the establishment of a larger number of *madarsas* schools and colleges for the education of people. Their establishment, as has already been pointed out, allowed a considerable degree of social mobility. It appears that the main objective of publishing a large number of books and the dissemination of their contents was, essentially, to teach the people methods and techniques to solve their day-to-day problems and to organize their life using this knowledge.

Here a moot question which requires some answer arises: if that were so, why did the medieval society in India limit the knowledge revolution only to paper manufacture and copying of manuscripts, rather than developing knowledge further by going over to the next stage of book printing, the technology of which was available? This is of particular significance in view of the fact that China had used the Indian technology of block printing for this purpose. It is all the more surprising as Buddhist priests in the seventh century used block printing to impose Buddha's image on silk and paper.

Why in India, while the first step in the knowledge revolution was taken, was the second not particularly when it had both the technology and the skilled manpower. The Indians must have had or at least seen the Chinese printed books. This is more intriguing in view of their awareness of the printing press. The Portuguese had brought a printing press, and had presented it to Jehangir, who did not show any interest either in the press or the clock which was also gifted.

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The answer perhaps lies in the social structure and culture of the period. As in the ancient period, during this period also the policy might have been to limit education to a few and not spread it to the masses. There had been, as a result of spread of education to a wider section of the population, protests by the aristocracy against the rise of those who were considered lowly by them, on being appointed to high offices as a result of education. In the elite group, the most vociferous were the immigrants who considered themselves as part of the ruling class and had wanted all the major appointments from amongst themselves. The limited availability of books in manuscript form, and the time taken in copying them, automatically prevented the spread of education.

Book printing in China developed as a result of the policies of the Chinese emperors in creating a class of professional administrators, to take care of the day-to-day problems of administration. In the absence of this tradition, India was not able to develop a class of professional administrators, who went through a course of study and a rigorous examination, the passing of which was a prerequisite for appointment in the imperial service, and promotion to higher posts.

This feature—the absence of institutions to produce professional administrators and its effect on the development of science requires study. The absence of a professional class of administrators might have been the result of a highly individualistic and personalized approach in education and in the development of technology as well as other areas. This also created a social and cultural ethos in accordance with the lack of development of institutions, which could not form the basis for an institutionalized approach to knowledge and development of technology.

In this context two other probable factors may be considered. Firstly, calligraphy by itself was fairly developed as an art and, along with the fancy embellishments, on the boundaries as well as the written text, it imparted an aesthetic value to the books produced during the period. This was not possible to get with printing technology at that stage. Consequently, perhaps the aesthetic reasons also dominated the tradition, and prevented book printing.

Judging from the type of education in the madarsas and the contents of manuscripts briefly indicated in Chapter I, the second probable explanation could be that all those who attended the courses in madarsas, and studied their books were considered fit to be administrators in the kingdom. In other words, the manuscripts now available of the period were essentially like textbooks meant to prepare people to handle administrative jobs. And with the exception of a few texts and commentaries, the possibilities of advancement in the then existing knowledge was limited.

Further, the Islamic tradition of calligraphy, along with the conservative approach of Ulemas, must have come in the way of adoption of printing technology. It is well-known that they had strongly opposed the printing of *Quran* in the beginning. The result of tradition and conservative influences thus thwarted the knowledge revolution, by containing the spread of education to a limited section of people and had its adverse impact on the linkage of science to technology. Moreover, limiting of education of artisans and craftsmen to theological knowledge must have also created a similar negative impact.

II. MATERIALS USED IN ANCIENT INDIA

Before the advent of paper-making industry in India the writing materials which were extensively used were the barks and leaves of trees (*tvak* and *patra*), silk or cotton cloths (*pata*), planks (*phalaka*), leather and parchment, metals particularly copper (*tamrapatra*), clay tablets, and rocks (*shila*). Specimens of old documents on all these materials are extant. It is not as if only edicts, inscriptions and grants have come down to us on such materials (e.g.

rock edicts of Ashoka and grants of Vallabhi rulers inscribed on copper plates), even literary works like plays (e.g. *Parijatamanjari*), poems (*Kurmasataka* and *Hanumadvimsati*) and music and songs (*Kudumiyamulau* and *Tallapakkam* compositions), are extant on stones and copper-plates. The renowned Arab bibliographer, Bin Ibni (d. AD 995) stated:

> The Arabs write on the shoulder bones of camels and on the leaves of date palm whereas the Indians use copper-plates, rocks and white silk.[1]

Ancient Indian literature has been preserved on palm leaves (the more common short and stiff *talapatra* and the broader and more flexible *sritala*) in the southern part of India. The bark of birch (*bhurjapatra*) were used in Kashmir and the northern regions of the country. The bulk of Indian literature in Sanskrit, Prakrit, Telugu, etc. has been preserved on palm leaves all over India. In Andhra Pradesh, the Andhra Historical Research Society alone maintains an Oriental Manuscripts Library of 1000 palm-leaf books. Kalidas referred to the birch-bark as a writing material. Greek testimony, of Nearchus and Curtis, also bears out the use in India (fourth century BC) of cloth and the inner barks of the Himalayan birch. Giving a description of writing materials of the province of Orissa, Sujan Rai stated:

> The people of that province would scribe on palm leaves by an iron pen which they held in their fists and would sparingly use the birch and ink.[2]

The same historian writing about Kashmir stated:

> There the people scribe mostly in the inner bark of *bhurjapatra* which grows in abundance in this country. The ink is so prepared that it cannot be blotted out by washing.[3]

State documents were also written on cotton and silk cloth (*pata*). Until very recently, in the Kannada region, the material commonly used and called *kaditam* was made of cotton pieces stiffened by a coating of dark paste and written over with chalk (*kathini*) or steatite pencil. Examples of this could be seen in the MSS libraries in south India. Again, wooden boards (*phalaka*) and bamboo had also been pressed into service for this purpose. Despite the keen sense of purity and pollution, ancient Indians did use leather to some extent, on which some documents have been discovered. Strabo referred to the use in India of parchment for state documents. Like palm leaf, metal plates particularly of copper (*tamrapatra*) were extensively used to record state edicts, grants and also literary works. The most remarkable literary records on copper-plates are those preserved in the Tirupati temple, carrying the entire volume of musical compositions of *Tallapakkam* composers of the Tirupati shrine.

Stones and sides of rocks were freely used to record royal exploits and grants. There is hardly a cave temple or a constructed temple in India which is not an imperishable library of this type of written material. We have an account of dramas preserved in stone inscriptions.

III. ORIGIN OF PAPER TECHNOLOGY IN INDIA

Generally, the Chinese are credited with the discovery of making paper, although it is highly probable that it was discovered earlier by other people, like the Aztecs and the Maoris. However from China, the knowledge of paper-making reached Korea (*c.* AD 610) and Japan (*c.* AD 625). The Chinese prisoners of war, brought to Samarqand after the battle of Atlakh near Talas, first introduced (AD 751) the technique of paper-making from linen, flax or hemp rags based on methods used in China. Ibn Nadim observed in *Al-Fihristi*:

> The Chinese write on Chinese paper made from a sort of herbage. This (industry) is a great source of income for the city.[4]

The Arabs learnt the technique of paper-making from the Chinese captives at Samarqand and diffused it westward. Al-Beruni stated.

> Paper was invented by the Chinese. The Chinese captives introduced it in Samarqand whence it diffused to other parts of the world.[5]

Paper mills were eventually erected at various centres, those at Samarqand and Khurasan being among the first. The Arabs improved upon the technique and supplemented linen with flax and other vegetable fibres. With the conquest of Sind by the Arabs, Khurasani paper was first introduced in India early in the eighth century AD, and it continued to be imported for several centuries.

Shams Siraj Afif in *Tarikh-i-Firozeshahi* had stated that scholars, poets and artisans were attracted to the courts of Sultan Muhammad bin Tughlaq and Firoze Tughlaq. The latter particularly received them with royal patronage and caused several new industries to be introduced in India. By this time paper had assumed great importance as a writing material, and it was very likely that paper mills might have also been erected by him. That a modest beginning had been made in that direction was amply borne out by the testimony of a contemporary historian, Abu Hamid al-Gharnavi, who stated:

> The Samarqandi paper supplanted the Egyptian paper just as the latter had excelled the Magribi paper. The paper made at Balkh favourably compared to that of Iraq, Khurasan and India.[6]

The reference to Indian paper suggests that the paper-making industry, however limited, had already been established in India, most probably in Delhi and Lahore, the two chief political and cultural seats of the Sultanate period.

It was not until the reign of Sultan Zainul Abedin of Kashmir (AD 1417-67) that the first pointed reference to the establishment of paper industry in Indian was found in the chronicles. His father Sultan Sikander (*c.*1386-1410), was ruling over Kashmir at the time of Timur's invasion of India (AD 1398). Sultan Sikander sent an embassy, led by his son, Shahi Khan, to that formidable personage and sought his friendship. Timur summoned him for a meeting but in the meanwhile political developments at home compelled him to leave India. He hastened to Samarqand but took along Shahi Khan and kept him virtually as a hostage until his death. Shahi Khan, who came to be known as Sultan Zainul Abedin, utilized the sojourn at Samarqand in the pursuit of knowledge. When he returned to Kashmir he brought with him many artisans and persons skilled in various trades with a view to introducing new industries there. These included paper-makers, book-binders, harness-makers and midwives. The author of *Tarikh-i-Kashmir* stated the following about Shahi Khan:

> During his stay at Samarqand he acquired knowledge. When he returned to Kashmir he brought with him a number of artisans skilled in different trades such as paper-makers, book-binders, carpet-makers, harness-makers and well trained midwives.[7]

His enthusiasm for the welfare and progress of Kashmir did not diminish even after ascending the throne. The same author stated elsewhere:

> He requisitioned the services of artisans from Iran, Turkey and particularly from Khurasan (being nearer to Kashmir). He made land grants to those artisans whom he had brought from foreign countries as an incentive to boost their respective trades.[8]

The Kashmiris learnt paper-making and improved upon the technique to such a degree that, within a few years, Kashmiri paper earned considerable reputation for its excellence. Indeed the Sultan considered it fit enough to be sent as a present to other contemporary kings. Never before did Kashmir witness such all-round progress as was brought about by Sultan Zainul Abedin. Contemporary rulers used to exchange presents with him as a matter of political expediency. Sultan Mahmud Begara of Gujarat and Sultan Abu Said of Khurasan sent some presents to Sultan Zainul Abedin who reciprocated by sending Kashmiri products and curios to the two rulers. The most prominent present was the Kashmiri paper. Paper was already being made at Khurasan and was not a unique thing. Hence, it follows that Kashmiri paper was far superior to the Khurasani one, and that was why it was sent as a present to Sultan Abu Said.

According to *Tarikh-i-Farishta* :

> Sultan Abu Said sent fine Arab horses and strong camels of good breed as presents to Sultan Zainul Abedin. Pleased with this act of courtesy, Sultan Zainul Abedin in return, sent saffron, paper, musk, perfumes, rose-water, vinegar, elegant shawls, glass bowls and other fine products of Kashmir industry.[9]

Kashmiri paper was in much demand in the rest of the country for writing manuscripts. It was used by all who wished to impart dignity to their correspondence. The pulp from which the paper was made was a mixture of rags and hemp fibre, obtained by pounding these materials. Lime and some kind of soda were used to whiten the pulp. The pulp was then placed in stone troughs or baths and mixed with water. From the mixture a layer of the pulp was extracted on a light frame of reeds. This layer was pressed and dried in the sun. It was then polished with pumice stone and its surface was glazed with rice water, After a final polishing with onyx stone, the paper was ready for use. Its main quality lay in its stoutness and durability.

IV. PAPER-MAKING CENTRES

With the rapid diffusion of technical know-how and the ever increasing demand for paper as a writing material, paper-making centres were soon established in different parts of the country. These centres in medieval India were in Sialkot (Punjab); Zafarabad in district Jaunpur (Oudh); Bihar Sharif in district Azimabad (Patna) and Arwal in district Gaya (Bihar); Murshidabad and Hooghly (Bengal); Ahmedabad, Khambayat and Patan (Gujarat); and Aurangabad and Mysore in the south.

Punjab had its full share in the developing paper industry. Sialkot alone had a number of paper-making concerns, where a variety of paper of different brands was prepared. Sialkot paper was white in colour and very stout. It was used throughout Punjab. Sialkot was perhaps the only paper-making centre in Punjab in the medieval time.

The very appellations of the brands of Sialkot paper clearly suggested that paper-making concerns were established during, or shortly before, the reign of Jehangir (AD 1605-27). Writing about Sialkot, Sujan Rai observed :

> The paper introduced here is fine; Man Singhi, Nim Hariri and Khasah-i-Jahangiri brands are especially fine, white, clean and stout.[10]

Raja Man Singh was a most trustworthy noble of the Mughals. Most probably the Man Singhi brand of paper was named after him. Similarly, the Khasah-i-jahangiri brand must have owed its origin to the name of Jahangir, the Mughal emperor. Details about the qualities of these brands are not available, but both must have had qualities of a high order. As for the

Nim Hariri brand, perhaps it had cotton and silk for its ingredients blended together, and must have been soft, glossy and strong.

Zafarabad is a famous town in district Jaunpur, Uttar Pradesh. It was once the seat of the government during the early period of the Sharqi dynasty. It was also known as Kaghdi Shahar (paper city). It produced a very fine, glossy and strong variety of bamboo paper. Generally two varieties of paper were produced here, namely, the polished one which was exceedingly glossy and the unpolished one The former variety was used for composition and transcription of books and was somewhat brownish-white in colour. Business accounts were also maintained on this paper until the beginning of this century. The unpolished paper was a bit thicker than the polished one. Silk merchants of Benaras used the coarse variety as wrappers for their wares. Even today there is a quarter in Zafarabad town known a 'Kaghdi Mohallah'. Zafarabad supplied paper to other parts of the country in large quantities.

Bihar had two major paper-making centres in medieval times, namely, Arwal town in district Gaya and Bihar Sharif in district Azimabad (Patna). Ghulam Husain Khan Tiba Tibai stated:

> Arwal and Bihar towns supplied fine paper which is still manufactured here. Investment of some capital coupled with more efficiency may well produce still finer paper.[11]

Bihar town produced large quantities of paper which were supplied to other parts of the province through the commercial market of Azimabad. As in Zafarabad town in Jaunpur, there is a quarter in Bihar town known as 'Kaghdi Mohallah', its residents being called 'Kaghdi'. Writing about the province of Bihar, Sujan Rai gave fleeting praise for the paper produced in Bihar town: 'The paper made here is fine'.[12] Beyond this no details about its quality are given. The Arwal town had numerous paper-making concerns. After the occupation of Bihar, the East India Company entered into contract with the people of Arwal for supply of paper.

In Bengal, Murshidabad and Hooghly were the major paper-making centres in the medieval time. At a later period, Dinajpur also started manufacturing paper. Dr Buchanan in his survey of the provinces of Bengal and Bihar gave an account of the manufacture of paper from *pat* or jute *(Corchorus olitorious)* at Dinajpur and in Bihar from *sun (Crotalaria juncea)*.[13]

It appears that Gujarat was by far the largest producer of paper. After meeting its own needs, it supplied paper to the rest of the country and even exported a considerable quantity to west Asian countries and Turkey. Ahmedabad, the capital of Gujarat was founded early in the fifteenth century and in less than a half century it developed rapidly. Sultan Mahmud Begara was particularly keen about its progress. Scholars, divines, artisans, etc. assembled at his court in large numbers. Paper-making concerns were established at Ahmedabad right from the beginning. Besides Ahmedabad, large paper-making concerns sprang up also at Khambayat and Patan. The paper made at Patan was known by the appellation, 'Patani' paper. A manuscript on the history of Bengal present in the Junagarh Public Library is written on Patani paper.

Ahmedabad was the largest paper-making centre. Paper produced here was exceedingly white and glossy. In no other part of the country was paper of such a high grade made. Paper of all sizes and description, thick and thin, including coloured paper of various kinds, were produced there. To cater to the needs of the business community, brown paper was also produced for account books. Paper with the glamorous appellation, 'Zarafshan', was also made at Ahmedabad. There are some manuscripts preserved in the Pir Muhammad Shah Library at Ahmedabad which are written on the 'Zarafshan' variety of paper. The salient features of Ahmedabadi paper were its extreme whiteness and glossiness. The author of *Mirat-i-Ahmadi* stated:

> Although Daulatabadi and Kashmiri papers are of fine quality, yet in point of whiteness and lustre the two varieties cannot compete with Ahmedabadi paper. Several kinds are prepared.[14]

However, there was one defect in the Ahmedabadi paper. During the process of manufacture imperceptible perforations were caused in the sheets of the paper. This was because of the physical features of Ahmedabad. The author of *Mirat-i-Ahmadi* explained thus:

> As this city is situated in the desert, particles of dust get unavoidably mixed with the pulp. They come out of the paper sheets when they are dried and polished, leaving behind imperceptible perforations. This is a defect.[15]

Inspite of this defect, Ahmedabadi paper was in great demand both at home and abroad, simply because of its whiteness, elegance and glossiness. It was exported to Arab countries and Turkey and merchants made huge profits through its export to other countries. The same author remarked elsewhere :

> Because of the whiteness of its colour, Ahmedabadi paper was exported every year by the merchants to India, Arab countries and Turkey worth tens of thousands of rupees like currency notes.[16]

During the Mughal period, Daulatabad with Aurangabad as its capital emerged as an important paper-making centre. The most noticeable feature of Daulatabadi paper was its durability and glossiness. There were numerous paper-making concerns in Daulatabad where different varieties of paper known by different appellations were produced. Daulatabad was the chief supply centre of paper to south India.

The town of Balapur in district Akola (Berar) was also a paper-producing centre in the medieval period and continued to be one for a long time. Some four or five kinds of paper of different hues and colour were made at Balapur. There is even today a quarter by the name of 'Kaghadipura' where the ruins of vats, employed for making paper can still be seen.

A paper-making concern was established at Mysore during the reign of Sultan Tipu. Grains of gold leaf were mixed in the pulp by means of a device and during processing these gold grains spread over the surface of the paper.[17] This special paper was meant for royal use, as can be seen in the private account books of Peshwa Bajee Rao, whose folios were similarly treated.

In course of time, the country was dotted with a large number of other minor paper-making centres.

Maler-Kotla[18] (Punjab) was once a flourishing paper manufacturing centre down to the first quarter of the present century, and so was Multan.

Sanganer[19] (in Jaipur, Rajasthan) was once famous for its dyed and stamped chintzes. Country paper is still manufactured there.

Kotah[20] (Rajasthan) has muslins, both white and coloured, and country paper as its principal products.

Tijarah[21] (in Alwar, Rajasthan) has weaving and paper-making as its principal industries.

There was formerly a small manufacturing centre of country paper at Kannauj[22] (in Farrukhabad, Uttar Pradesh).

A special paper used of native account books is still made at Mathura.[23]

Kalpi and Pukharayan in Kanpur district have long been well-known for hand-made paper. In addition to these two centres, there have also been hand-made paper units in Kanpur, Lucknow, Allahabad, Faizabad, Rampur, Almora, Muradabad, Mathura, Dehradun and Sultanpur.

A small quantity of hand-made paper is produced at Hariharganj[24] (in district Shahabad, Bihar).

The country paper industry at Kalita[25] (in district Pabna, now in Bangladesh) has almost died out, killed by competition from the Bally and other paper mills.

At Panchamnagar[26] (in district Damoh, Madhya Pradesh) the production of native paper has greatly declined. The paper is used by money-lenders for their account books.

The paper and cloth of Dharangaon[27] (in district East Khandesh, Maharashtra) were formerly held in great esteem. Today, the manufacture of this paper has entirely ceased.

Erandel[28] town (also in district East Khandesh, Maharashtra) is a place of some antiquity. It was formerly celebrated for its coarse native paper, an industry which still survives to a limited extent.

At Poona[29] the manufacture of paper by hand, formerly of some importance, has of late greatly declined. Paper-making was said to have been brought to Poona from Jaunpur. According to the paper workers, the site on which they built their houses and factories was given to them free of cost by the Peshwa to encourage the craft. Of the forty factories only eight remain, seven in Poona and one at Bhamburda. The paper made at Poona was strong and lasting but had no special peculiarity or excellence. Unlike the practice at Nasik and Jaunpur, where rags were used, at Poona paper was made solely from waste paper.

Besides the above mentioned centres, other centres which specialized in different types and qualities of paper were Bagalkot where rough white paper was made; Kolhapur which made coarse but white paper; Gokak which made coarse paper. Koratla in district Karimnagar; Mujahidpet in district Nanded; and Sembiem in district Chenglepet, also made small quantities of paper. Other places included Dharwar, Gadag, Gutal, Hubli, Karajgi, Navelgand, and Ranebeunur.[30]

V. IMPORTANT VARIETIES OF PAPER

Several varieties of paper were made with varying degrees of excellence and for different uses. Among the most reputed brands of paper were the Zarafshan variety of Ahmedabad; Man Singhi, Nim Hariri and Khasah-i-jahangiri of Sialkot; and Bahadur Khani, Saheb Khani, Murad Shahi, Sharbati, Qasim Begi and Rùbakari of Aurangabad. Most of these varieties of paper are admirably preserved in the Habibganj section of the Maulana Azad Library, Aligarh. Brief descriptions of important varieties and types of paper made are presented below:

1. *Ahmedabadi:* Several types of paper were made with varying degrees of thickness. Some of these were fine and super-fine. The Zarafshan variety was golden coloured. The salient features of Ahmedabadi paper were its extra whiteness and glossiness. The Habibganj specimen is a bit thick and not very white. It may have lost much of its whiteness due to passage of time.

2. *Kashmiri:* This paper was stout and glazed. Some paper-making concerns turned out super-fine paper, commonly called silken paper because of it being soft, thin and glossy. Quite a few manuscripts preserved in Habibganj section are on silken paper, which is thin and pale green.

3. *Khasah-i-jahangiri:* This paper was exclusively made at Sialkot. The Habibganj specimen is glossy, thin, polished and bluish white. Another specimen is pale grey.

4. *Hyderabadi:* There were two quarters in Hyderabad where paper was made, namely, Mohallah Miyan Mushk and the Kaghdi Gorha. Some seven specimens are preserved in the Habibganj section which were produced during the reign of Qutub Shahi rulers. Some are polished and of brown colour with very fine shades of difference.

5. *Faizabadi:* Habibganj specimens suggests that Faizabad was also a paper-making centre. The unpolished one is of medium quality and is pale yellow. The polished one is dark yellow.

6. *Kanpuri:* Paper was prepared from bamboo and was greyish in colour.

7. *Aurangabadi:* There were numerous paper-making concerns at Aurangabad which turned out several varieties of paper. Generally Aurangabadi paper was glossy and stout. The notable varieties of this paper were: (i) *Bahadur Khani:* It appears that this variety was named after Bahadur Shah of Gujarat (AD 1526-37), who had occupied Daulatabad. He is believed to have branded this variety as Bahadur Khani, just as a particular kind of cloth and a gun were also named after him. This variety of paper is of medium quality and somewhat thick but stout and durable. (ii) *Sahib Khani:* This variety was thick and of medium quality. (iii) *Murad Shahi:* The Habibganj specimen is somewhat thick but of fine quality. It was named after prince Murad, Akbar's second son, during his stay in the Deccan. (iv) *Sharbati:* This variety is also thick and fine but differs from Murad Shahi in that it is pale green. (v) *Qasim Begi:* The Habibganj specimen is pinkish (*Gulabi*). This variety was made in varying grades of thickness but invariably of red colour. (vi) *Ruba-Kari:* This variety was made in four or five different grades and was mainly consumed in offices.

8. *Balapuri:* Balapur was also a paper-making centre in medieval times. Some four or five varieties of different colours were turned out by paper-making concerns, ranging from brown through to ordinary white. However, it was not so glossy as Ahmedabadi paper.

VI. TECHNIQUES OF PAPER-MAKING

Tools and Equipment

Six main tools and applications were used for paper-making First, the *dhegi* or great hammer, a long heavy beam poised on a central fulcrum and working in a long pit two or three feet deep. The head of the hammer was a heavy block of wood fixed at loops to one end of the main beam, with its face strengthened by four thick, polished steel plates. On the upper surface of the other end of the main beam two or three steps were cut. The hammer was worked by three or four men together forcing down the beam and letting it rise by alternately stepping on the beam and on the edge of the hole.

The second equipment was a screen called *chhapri.* It was made of the stalks of white conical-headed amarnath *(Amaranthus globulus),* on which the film of paper rested when the frame was brought out of the cistern, and the water allowed to pass through it.

Another tool was a rectangular teakwood frame or *sacha,* two and a half feet by two, with eight cross bars.

A soft date-palm brush or *kuncha* was used for spreading the sheets against the cemented walls of the room. This brush was not always required, as the paper was generally spread in the sun on rags.

A piece of agate was used which has a polishing stone. Smooth teak-wood boards, each about two feet by three, were required to lay the paper and over which it was rubbed with the polishing stone or shell.

Process of Making Paper

The techniques of paper-making was more or less the same throughout the country, differing only in the preparation of pulp from different materials. The skill of the Indian artisan streamlined the product to greater excellence. Generally, rags were thoroughly cleansed, boiled and beaten into a pulp with water to the consistency of a cream. A finely woven wire sieve was dipped into the vat (*daba*). A horizontal shaking motion was given to the sieve, which caused the fibres to felt or interlock, the water draining away through the fine holes in the sieve. The sheet was then placed between lengths of felts and subjected to pressure. After drying, the paper was dipped in size (*mandi*) to render it non-porous and finally dried and smoothed by passing it through rollers under pressure. To size the paper and render it fit for ink, a somewhat gelatinous glue was first prepared in a vessel. A rod was laid over the vessel and a cleft stick was used for holding the sheet of paper during the process of dipping. As soon as the paper had been sufficiently saturated, it was withdrawn by gently rolling it round the stick which had been laid over the vessel. The sheet of paper was then hung to dry. And finally it was smoothed and polished by being rubbed on wood with the convex side of a shell.

Jute, *sun, ambaree, moorve,* old sacks and fishing nets were also employed. Dr Forbe Royle observed that the fibrous parts of many lily and aloe-leafed plants were converted into excellent paper in India, where the fibres of tilaceous, malvaceous and leguminous plants were also employed for the same purpose.[31] Paper was also made from *Sanserviera* in Trichinopoly. Some paper was made at Madras from unbleached *Agave* alone, as also mixed with old gunny-bags.[32]

The process of making paper from waste paper was not as elaborate as the one from sacking. The waste paper was torn to pieces, sorted according to colour, moistened with water, taken to the river and pounded with stones, and washed for three days. It was then taken to a cistern (a cement-lined tank) about 7ft × 4ft × 4ft deep, half-filled with water. The pulp was thrown into this cistern. When it was thoroughly dissolved, the workman sitting on the edge of the pit, bending over the water, took in both hands the square frame which held the screen serving as a sieve, passed it under water and drew it slowly and evenly to the surface; such that, as the water passed through, a uniform film of pulp was left on the screen. The screen was then lifted up and turned over, and the film of paper was spread on a rag cushion. When sufficient layers has been heaped on this cushion, about 9–14 inches high, a rag was spread over them and a plank weighted with heavy stones was laid over it. When this pressure had drained the water and some of the moisture out of the stock of paper, the stones were taken away and two men, one standing at each end of the plank, seesawed over the bundle of paper by hand. When it was well pressed the paper was peeled off, layer after layer, and spread to dry either on the cemented walls of the building or on rags laid in the sun. When dried, each sheet was laid on the polished wooden board and rubbed with a shell till it shone.

The paper made by this process, though rough and of a dingy yellow, was strong and lasting and was highly prized by the merchants who used it for their account books. However, when the cheaper machine-made imported paper came on the scene, the demand for the local paper declined.

Paper-making[33] was introduced in Nasik in about AD 1800. Nasik was once an important and prosperous paper-making centre, but now has fallen into decay. The paper was made from rotten gunny-bags, which passed through the following 13 elaborate processes:

1. The material was cut into small pieces, moistened with water and pounded by a heavy fixed hammer, the *dhegi.*
2. It was washed in plain water.
3. It was moistened with slaked lime and left in a heap on the floor for seven or eight days, then pounded again, heaped and left to lie for four days more.
4. It was washed a second time in water.
5. It was mixed with *khar* (impure carbonate of soda), in the proportion of one part of soda to 32 parts of rags, pounded and kept overnight.
6. It was then washed a third time.

7. It was again mixed with *khar* in the proportion of one part *khar* to 40 parts of the pulp, dried in the sun to bleach, and pounded three or four times.
8. It was for the fourth time kept in water overnight and washed the next morning.
9. It was mixed with country soap in the proportion of about one part of soap to every 27 parts of pulp, pounded and dried.
10. It was washed a fifth time.
11. It was then thrown into a cement-lined cistern, about 7ft × 4ft × 4ft deep, half-filled with water, and when thoroughly loosened and dispersed through the water, the workman sitting on the edge of the pit leaned over the tank and took in both hands a square-cornered screen or sieve, passed it under the water and drew it slowly and evenly to the surface, such that, as the water passed through, a uniform pulp was left on the screen.
12. The screen was lifted up and turned over so that the film of paper was spread on a rag cushion; when layers had been heaped to the height of 9–14 inches, a rag was spread over the heap and a plank weighted with heavy stones was laid over it. When the pressure had drained the paper of some of the moisture, the stones were removed and two men, one standing at each end of the plank, proceeded to seesaw over the bundle of the paper; when it was well pressed the paper was peeled off, layer after layer, and spread to dry on the cemented walls of the building.
13. When dry, each sheet of paper was laid on the polished wooden board and rubbed with a smooth stone till it shone.

Here, again the four main tools and appliances used were: (i) the *dhegi*, a large hammer; (ii) *sacha*, a rectangular teakwood frame, about 2.5ft x 2ft, with eight cross-bars; (iii) *chhapri*, a screen made of stacks of white conical-headed amarnath (*Amaranthus globulus*); and (iv) *kuncha*, a soft date-palm brush. The paper made at Nasik, though rough and dingy yellow in colour, was strong and durable.

Rough white paper called Bagalkot paper, was made in Bagalkot, Maharashtra.[34] The method of making paper here was more or less similar to that employed at Poona and Nasik. Here rags, coarse cloth or *gunny pats* were employed as raw materials to make pulp. These were cut into pieces about four inches long. The pieces were soaked in water, laid in a stone receptacle and carefully pounded with a heavy wooden pestle or *langar*. The pounded material was then rolled into a large ball which was washed in a river. Next day the ball was soaked in lime-water and was again pounded and made into a ball. After allowing the materials to lie for four days on the floor, the ball was again soaked in water and pounded with a powder of *papadkhar* (impure carbonate of soda) with an equal quantity of *sarala*. After washing it four times, the mixture was dipped for one day in a cement-lined cistern, in which the ball dispersed and covered the water with a thick yellowish film. Next day the mixture was gently stirred until the whole content of the cistern was charged with a thin pulp of paper.

The *sacha* was a flat sieve or strainer varying in size according to the size of the sheet of paper to be made, but usually about 18 inches square. It was surrounded by a plain wooden frame into which were lightly fastened a number of hair-like threads of bamboo fibre laid close together. Holding the strainer in both hands a worker lay by the side of the cistern and dipped it about a foot under water. Taking care to keep it level, he brought it slowly to the surface, catching the floating films as an even layer over the whole strainer. He held it for a few moments to drain out the water and then turned the strainer to place the layer of paper on the floor. This process was repeated and the layers were heaped one over the other, till the heap was about nine inches thick. The heap was then pressed under a wooden plank on which two men stood to squeeze out water. Each sheet of paper was then separated, pasted to the walls and, after a short time, hung on ropes to dry.

When thoroughly dried, the sheets were softened by rubbing both sides with rice paste. They were dried again and piled in packages of 20 sheets each. Each package had one sheet soaked in water and this, kept under pressure for one day, moistened the whole package. Each sheet was then laid on a smooth plank and rubbed with a soft stone till it shone. It was then ready for use. The Bagalkot paper was largely used for the account books of traders.

Kolhapur[35] has also been a centre of handmade paper. The Kolhapuri paper was coarse but strong and glazed. Sacking, the main raw material, was brought from Belgaum, Kagnoli and other places. About 96 pounds of sacking were cut into small pieces and left in lime water overnight. The material was then reduced to a pulp in the *dang*, which consisted of heavy wooden lever with a heavy wooden pestle. The lever was fixed by axles on two upright posts driven into the ground. At the end of the pestle, nearest the ground, two heavy iron teeth were fixed each weighting about ten pounds. The whole weight of the pestle was about 50 pounds. This apparatus was used to pound the fibrous material into a pulp, for which two men were employed in alternately raising the pestle and allowing it to fall with a heavy thud on a stone slab. The slab was 2.5 ft square, firmly fixed in the ground with a terraced floor round it. Three men were required to work the *dang*, two at the lever and one to keep the sacking between the stone and the pestle. Fourteen days were required to reduce 96 pounds of sacking to a coarse pulp.

This pulp was then washed in a river or pond, by placing about 12 pounds in a piece of *daugri* (coarse cloth), gathered at the corners and tied to the waists of two men. These men stood in the water up to the waist and, by continually stirring the pulp, brought all dirt and impurities to the surface and carefully removed them. It took hours to wash 96 pounds of pulp. The washed pulp was allowed to drain of water and then mixed with about half a pound of carbonate of soda or *papadkhar* and two pounds of lime. The material was pounded in the *dang* for three days, for about 10 hours at a time, after which it was again washed and two pounds of country soap and two pounds of lime were added during each intermission. Four men were employed to tread the pulp on a terraced floor for several hours. The material was then made into large lumps and left for four days to bleach and putrefy. On the fifth day it was again, for the third time, put into the *dang* and made into a thin pulp. The bleached and putrid mass was then put into a lined cistern filled with water, 4 ft square and 4 ft deep. The mass was stirred with a bamboo and the process of paper-making began.

The gelatinous mass was received on a mould called *khasi* which consisted of a wooden frame, 3 ft long, 2.5 ft broad and 1.5 inches deep, with cross wooden bars at 3-inch distance. Over this frame was placed matting called a *chhapri*, made from the blades of *kavas* grass woven with horsehair. Over this matting another thin frame of wood was fitted close to the mould. The second frame was used to keep the stuff on the mould and to limit the size of the sheet. A man sat with the mould in both hands on the edge of the cistern, and inclining the mould a little towards it, dipped it into the cistern and lifted it horizontally, mildly shaking it to distribute the stuff over it. This was repeated three or four times until a sufficient quantity of pulp settled on the mould. The matting was then taken off the mould and placed on a terraced floor called *baksar*. On depositing it on the *baksar* the side on which the paper was formed was turned towards the floor and pressed by hand to squeeze out the water, after which the matting was carefully removed so that the sheet of paper remained deposited on the floor. Sheet after sheet was then taken off and laid one over the other in a pile, until the pulp in the cistern was exhausted. The pile was then placed between two stout boards, over which a couple of heavy stones were placed and a man kept stamping on the board with his foot to squeeze out the superfluous water. The sheets were then carefully separated one by one and dried on the walls which had been washed with white earth and water. As the water was absorbed the paper dried and fell to the ground.

At this stage the crude paper was called *rast.* It was again placed in the sun for a short time to dry. The dried sheets were piled and pressed with great force to render them flat and smooth. The paper then required finishing by being sized and polished. For this purpose a rice gruel mixed with powdered *turti* or alum was applied on both sides of the paper with a brush and allowed to dry in the sun on a rope. It was then polished on an even board by smooth flint stone or shell until it was glazed. The sheet was then cut and the edges made even.

Three varieties of paper were prepared, namely the *vahicha* which was used for books; the *kharchi* for ordinary use; and the *rast* used as wrappers. The first variety was of a superior grade and was available in a size of 18 inches long and 12 inches broad. The *kharchi* paper was a little inferior and was sold in a size of 14 inches long and 12 inches broad.

Paper-making at Kolhapur, as elsewhere, declined chiefly owing to import of better and cheaper paper.

Paper is still manufactured to some extent in district Satara[36] (Maharashtra). Gokak[37] town in the district Belgaum was once famous for its dyers and is still noted for a coarse kind of paper made in large quantities.

Coarse paper is made at Koratla[38] in district Karimnagar (AP) and is still used by *patwaris* for their village account books. Coarse paper is also made in Mujahidpet[39] in district Nanded (AP). Sembiem[40] town in district Chinglepet (Tamil Nadu) has ten small paper-making establishments.

The ever increasing demand for paper for a variety of uses made it one the most important consumer goods. The handmade paper industry flourished for a considerable time. However, with the arrival of cheap machine-made paper in the market, the handmade paper has lost ground. At some places the industry is now almost extinct, at other places it is just lingering.

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CHAPTER XI

Minerals and Metals in Medieval India

Arun Kumar Biswas

I. INTRODUCTION

Most Indian traditions related to extraction and processing of gems, non-gem minerals and metals had originated during the ancient period, and we have given exhaustive accounts of the same elsewhere.[1-4] We divided the entire ancient period up to AD 1200 into ten eras: pre-Harappan, Harappan, post-Harappan Vedic, post-Vedic Historical, Persio-Greek, Maurya, Roman, Indo-Scythian, Gupta and post-Gupta periods. We have carefully documented India's pioneering scientific activities in the areas of agate, carnelian, conch-shell, pearl, beryl, corundum, diamond, metallic ores, and metals and alloys like zinc, brass, iron and steel.

It would not be an exaggeration to say that up to the Gupta Period (fifth century AD) India was certainly one of the leading countries in the world in the fields of gems, minerals and metals (as well as in mathematics, astronomy and medicine). At the same time many ideas did flow into India, particularly from the Chinese and the Persio-Greek worlds. It is evident therefore that ancient India had a strong material tradition based on the spirit of enquiry, logic, pluralism and receptivity of foreign ideas.

We have tried to show in our chronological presentation and sociological analysis[5] that Indian science and technology prospered in the ancient world whenever the socio-political factors, like suitable economic challenges and opportunities, ideological motivation, political stability, appropriate contact with the outside world (stimulating and challenging but not overwhelming), etc. were conducive. In our critical analysis[5] we could also deliberate on the issue of medieval decadence. The scholars are divided in their opinions about the dating of transition between the ancient and the medieval eras in India. The date of AD 1200 is a tentative one and it is not universally accepted. It is safer to think of the transitional period running into several centuries starting with the rise of Islam in Asia (or downfall of the Gupta empire) and the consolidation of the Islamic power in India.

We have deliberated on the reasons behind the medieval decadence of Indian science.[5] Many scholars starting from Al-Beruni[6] up to Debiprasad Chattopadhyaya[7] have dwelt on the adverse factors of Hindu casteism, vainglory, theological fundamentalism, obscurantism, etc. We agreed with Chattopadhyaya and at the same time pointed out[5,8] the incomplete nature of his analysis. Chattopadhyaya failed to reckon that the vice of religious fundamentalism and theological obscurantism hurt not only Hindu science but also Muslim science (and even the medieval sciences in China and Europe). Quite strangely, many scholars have ignored the fact that Al-Beruni was not at all kind in his words to Muslim expansionists. He wrote about the insurmountable 'barriers separating the Muslims and Hindus', 'the repugnance of the Hindus against foreigners', 'their deeply rooted hatred' towards the invaders, how 'Mahmud utterly ruined the prosperity of the country' and why 'Hindu sciences have retired far away', etc.[9] Sachau commented that 'in his work on chronology, Al-Beruni reproaches the ancient Muslims with having destroyed the civilization of Iran'.[10]

The barbarity of the early Muslim invaders in India shocked even the Arab and Persian intellectuals. Shaikh Bu Ali Sina, a respected physician and biologist, refused to come to India with Mahmud, whose plunder included destruction of Indian science. Thus, the early impact of Islam on Indian science was destructive.[11] No doubt many concourses took place between Muslim scholars like Jabir Ibn Haiyan (AD 776), Al Khwarizmi (AD 800-50) Al Kindi (AD 800-73), Al Razi (AD 850-923) and Al-Beruni (AD 973-1048) and Hindu scholars. But this was more of a one-way traffic of ideas. The Islamic science reached its zenith during the eighth to the twelfth centuries AD and this beneficially influenced Europe but not India. Muslim forces were defeated at Tours in Europe in AD 732, and thereafter the presence of Muslim scholars like Ibn Sina (AD 980-1037) and Ibn Rushd (AD 1126-98) in Spain helped in the transmission of Greek, Hindu and Arab sciences to Europe through the medium of Latin. What happened to eleventh-twelfth century Spain did not take place in Sind. The Hindu India was denied of political independence as well as the beneficial influence of Islamic scholars of science, such as those who flourished in Cordoba, Spain.

Then Islam itself turned its back on science after Ibn Rushd's death in AD 1198. Even earlier, Al Mutawakkil (AD 847-61) had reversed Al Mamun's liberalism to non-Muslims and thereby initiated Sunnite onslaught on pluralism and science. Al Ghazzali (AD 1058-1111) preferred mysticism over reason and logic. Half a century later, Ibn Rushd attacked Al Ghazzali, but his anti-mysticism was disapproved of by the Muslim church. Fortunately, Ibn Rushd (also known as Averroes) and his writings influenced Europe for centuries. In AD 1245 Robert of Chester translated Al Khwarizmi's *Algebra* which itself was derived from Brahmagupta. Thus Muslim scholars fulfilled their historic mission of transmitting Greek and Indian (Hindu) science to Europe. They could not perform a similar beneficial role in India because their intellectual tradition had almost collapsed outside the boundaries of Spain. Theological obscurantism eclipsed not only Hindu science after the fifth century AD but also Muslim science after the twelfth century AD, and almost succeeded in stifling European science which was rescued by the heroic efforts of Copernicus, Luther, Bacon, Galileo, etc. Additionally, the invaders did their best (or worst) in ruining science throughout the ages. In AD 1199 Muhammad Bakhtyar invaded and sacked the Buddhist monastery of Odantapuri in Bihar, burning a great number of books in the libraries. In AD 1258 there was massacre in Baghdad by the Mongols who had been Buddhists at one time and, according to Al-Beruni, resented the expansion of Islam into central Asia. Within a span of sixty years, Indian science and Arab science received blows from invaders and suffered irreparable damage. In brief, the characters of Muslim influences that came to India and went to Europe were entirely different. By the time Islam consolidated its forces in India, its scientific spirit had suffered decadence. The causes of decadence of Hindu science (after fifth century AD) and of Muslim science (after tenth century AD) were remarkably similar: vainglory, theological obscurantism and fundamentalism.

Our major criticism[8] against Chattopadhyaya's paradigm[7] had been that it was incomplete and emphatic on Hindu deficiencies only, avoiding the issue of Islamic expansionism. We cannot discuss Indian science of the medieval period ignoring the masterly treatment of the history of Islamic science as documented by George Sarton.[11] If we had been slow in developing our own paradigm of Indian science, it was because we wanted to be surer of the facts. We have in fact counselled cautious development of an open-structured paradigm[8] which would invite accumulation of more historical data and not shy away from certain unpleasant facts to save a rigid and pre-conceived paradigm.

In this connection we wish to draw attention to the valuable contributions of Professor A. Rahman[12-13] in regard to the survey of science and technology in medieval India. His views may not be in perfect consonance with ours but we do submit that what he has stated so far does not negate our paradigm outlined in the previous paragraphs. Rahman's conclusive remarks may be partially quoted in support of our views:

> The pluralistic tradition of Hinduism and the pluralistic ethos created by Sufism led to the co-existence of the two streams.... It appears that the two different processes remained at work during the period, one towards integration of the two traditions and the other keeping them apart.... Despite the general ethos of bilingualism and plurality, all that was achieved was the availability of translations. Despite many books written combining the two traditions, an integrated simple tradition did not develop to create a base for further development of science to a new stage of development or providing a new direction.[13]

Rahman does not accept Sarton's remarks about the decadence of Muslim science after the twelfth century and its insignificance after the fourteenth century. But the data compiled by Sarton[11] and even by Rahman himself[12] clearly substantiate Sarton's views. The amount of original scientific literature in Arabic and Persian after the fourteenth century is indeed very small. Rahman admits that 'there is some evidence of translation from Sanskrit to Arabic and Persian, and *to a lesser extent* (italics are mine) from Arabic and Persian to Sanskrit.'[12] Two parallel cultures thus co-existed in India under considerable strain.

During the period tenth-eighteenth century scientific literature in India flourished in two parallel streams—Sanskrit and Arabic/Persian—with occasional interactions and translations, particularly in the fields of mathematics, astronomy and medicine. Literature in alchemy, gemmology and metallurgy was not so voluminous. In technological subjects, however, like those relating to gems, minerals and metallurgy, there was better interaction and continuity despite the paucity of written material. Whereas astronomy, astrology, etc. were the concerns of the theologians and scribes, mining and metallurgy were the means of livelihood for countless artisans who were poor and hardly concerned about theological issues.

In this paper, we would attempt to provide a *glimpse* into the tenth-eighteenth century AD Indian scenario of gems, minerals, metals and alloys—their extraction, processing and uses. The treatment would *not* be exhaustive; it would merely touch upon a few selected topics assisting in the build-up of our paradigm on the subject. First, we would deliberate on specific gem-minerals like pearls, corals and diamonds, discuss the reasons for the decline of diamond trade in India, and tabulate the Persian/Arabic terms for gems as introduced in India. We would then pass on to a few non-gem minerals like salt, *reh*, zinc, lead and iron ores and the respective metals. Various alloys and their uses would be discussed. Iron-carbon alloys like wootz and brass of different compositions were indigenously developed in India. On the other hand, there were distinct foreign influences in the development of Bidri Ware, tin-coating technology and other compositions coming from western and central Asia. At the end, we would revert back to the development of our paradigm on Indian science and deliberate on the reasons underlying the collapse of the indigenous science and technology in India during the late eighteenth century.

II. SPECIFIC GEM MINERALS

Let us begin with two soft gem materials which are of organic origin: pearl and coral. Pearl fisheries had flourished in ancient India. In the seventeenth century, Tavernier reported the trade going on in the gulfs of Persia, Sri Lanka and south India. He observed that the oysters of the Manār Strait opened by themselves, spontaneously, 'five or six days sooner than those of the Gulf of Persia, because the heat is much greater at Manār'. The latitudes in the gulf between Sri Lanka and India are between 8-9° whereas that in the island of Bahrein is 27°. Tavernier also corrected the earlier erroneous impressions 'that the pearl originates from the dew of heaven, and that but one is found in each oyster'. Pearl-fishing in the Manār used to take place twice a year, during March-April and August-September ('the heavier the rainfall, the better the pearl-fishery'), and the sale lasted from June to November. Tavernier wrote:

> It should not be supposed that a great profit is earned by those who fish for pearls; for if the poor people who engage in it had anything else to do, they would leave the fishing, which merely saves them from dying of hunger... Those who fish like to know beforehand whether it will pay.... The people of Manār are better fishers, and remain for a longer time under the water than those of Bahrein; they do not place any clips on their noses nor cotton in their ears to keep the water from entering, as is done in the Persian Gulf[15] (pp. 91-4).

The pearls at Manār, usually 2-4 carats in weight, were 'the most beautiful, both as regards water and roundness, of all the fisheries'. The Portuguese 'used to protect' the poor fishermen of Manār from the Malabaris, but that was before Tavernier's time, when the Dutch displaced even the Portuguese and extracted not only the 'protection levy' but also one day's catch (in a week) from the fishermen. The large trade of pearl and other precious gems at Portuguese Goa had become, during Tavernier's time, a thing of the past. The pearl trade prospered under the Dutch. The Indians liked the round as well as the 'baroque' (irregularly shaped) pearls. The sketch of the largest pearl which Tavernier saw and drew (the 50-carat, yellowish, pear-shaped one, hanging from the neck of the peacock in the celebrated throne) looks like an oblong hanging water droplet. Finally, Tavernier made the following interesting comment:

> All the Orientals are very much of our taste in matters of whiteness, and I have always remarked that they prefer the whitest pearls, the whitest diamonds, the whitest bread, and the whitest women[15] (p. 91).

Tavernier gave some details about coral fishing and trade during his time. He mentioned seven areas in the Mediterranean Sea region where coral fishing was done: three areas around the coasts of Sardinia-Alghero, Boza and St Pierre; fourth, the island of Corsica; fifth, the coast of Sicily near Trepani; sixth, the coast of Algiers; and seventh, the north coast of Tunis. Tavernier noted that, whereas coral did not rank among precious stones in Europe, the people in the east preferred this, 'one of the most beautiful of Nature's productions', to precious stones. Tavernier observed: 'It is much to be wondered that the Japanese give so much money for a fine piece of coral.... The common people wear it and use it as an ornament for the neck and arm throughout Asia, but principally towards the north in the territories of the Great Moghul (Aurangzeb), and beyond them, in the mountains, of the kingdoms of Assam and Bhutan'[15] (pp. 104-7).

A small town named Lantegree in Maharashtra was a great centre of coral-polishing in the early seventeenth century. The preference of the Indians and other Asians for coral was manifest even during the ancient period, and the *reason* for this preference has been the subject of many dissertations. Many travellers like Pliny and Marco Polo attributed the preference for coral 'to the way its tints adapt themselves to set off a dark skin (of the Asians)'. The real reason could be a religious antecedent. The reddish yellow coral is known as *rudrākṣa,* the eye of the Śiva, a symbol of renunciation and spirituality. It must have gained popularity during the Tantric period of Hinduism and (Mahāyāna) Buddhism. The 'ornament for the neck' used by the common people was a rosary of coral beads, which were counted during prayers.

The Indian tradition of jewellery made of rock crystal is very ancient but not well-documented. The present author has suggested[3] that the south Indian generic term *vel-ur* stood for white crystal town and gave rise to the more popular terms of *veluriya* or beryl and *veloari* or rock crystal. There was widespread use of chalcedonic and crystalline quartz (in ancient India), which were available in the rocks near Tanjore and the estuaries of Krishna and Godavari. Ball reported[15] (p. 502) that the lapidaries at Vellum (lat. 10°43' and long. 79°12') had skilled workers in different varieties of rock crystal, such as the ordinary pellucid quartz, smoky quartz, cairngorum and amethyst. The last was brought from Kangiam in Coimbatore, and the rest derived from Cuddalur (tertiary) conglomerates. The ornaments made were chiefly of brooch stones cut in brilliant, rose and other patterns. Godavari district, Hyderabad state and Sambalpur district of the Central Provinces also provided brilliant rock crystals.

Aurangpur of the Gurgaon district, 15 miles south of Delhi, had Aravalli quartzites from which quartz crystals were extracted, and these might have been used for making vases and ornaments. Tavernier saw Aurangzeb drink from a large cup of rock crystal placed on a golden saucer, enriched with diamonds, rubies and emeralds. What a sight! After the 1857 War of Independence, the Delhi palace was looted and found to contain many drinking vessels, vases and pitchers made of rock crystal, which were later described by Valentine Ball.

Chalcedony is known as a compact of silica and hydrated silica, slightly lighter and softer than quartz. Its many varieties are available in India: carnelian (red), sard (brown), plasma (dark green), heliotrope or blood-stone (green, spotted with red), agate and onyx (banded structure), etc. Agate and carnelian were mined, processed and used in India even in the Pre-Harappan times. Yellowish varieties, containing hydrated ferric oxide, used to be dehydrated on heating, and thus reddened to the anhydrous ferric oxide stage and beautiful carnelian in an age-old practice. The best known deposits were found in the Rajpipla hills at Ratanpur, on the lower Narmada river. Deposits of carnelian were mined and processed also near the Mahi river, north of Baroda.

The mining and working of stones at Ratanpur were vividly described in 1878 by J.M. Campbell (Bombay Gazetteer, vol. VI, p. 205) and reproduced by Valentine Ball[14] (pp. 507-13). A suitable extract is given below:

> The mine shafts are about 4 feet in diameter, and on an average about 30 feet deep. At the foot of each shaft, galleries 5 feet high and 4 feet wide branch off on all sides. These passages, seldom more than 100 yards long, in many cases join the galleries of other mines. At the mine mouth, the stones are chipped, and the likely ones carried to Ratanpur, the village of gems.
>
> The contractor divides the stones into two classes, those which should, and those which should not be baked. Three kinds are not baked: onyx called *mora* or *bawa ghorī*, the cat's eye called *cheshamdar* or *dola*, and a yellow half-clear pebble called *rorī* or *lasania*. The other kinds of pebbles are baked to bring out their colours. During the hot season, the stones are spread in the sun in an open field. During other seasons, the stones are gathered in earthen pots and heated in piles of ignited cow dung cakes.... Then the stones are taken to Broach and Cambay.
>
> By exposure to sun and fire, maize yellow gains a rosy tint, orange is intensified into red; the hue of the red carnelian varies from the palest flesh to the deepest blood red.... The larger and thicker the stone, the more it is esteemed. Four kinds of agates, the common, the moss, the kapadvanj, and the veined, rank next to the Rajpipla carnelians.

> The moss agate, *suabhaji*, comes from Budkotra, 3 miles from Tankara in Morvi. Kapadvanj provides another variety of agate. The most valued Cambay agate, the veined agate, *doradar*, comes from Ranpur in Ahmedabad.
>
> Of other stones processed in Cambay, jasper or bloodstone, the chocolate stone, a variegated pebble known as *maimariam* and the rock crystal are found in Gujarat. The lapis lazuli, obsidian and the blue stone *piroja* (turquoise) are foreign stones brought from Bombay. The rock crystal comes from Tankara in Morvi, the best varieties from Madras, Ceylon and China.
>
> The rough stone generally passes through three processes, sawing, chiselling and polishing (these were described in detail).... Cambay agate ornaments belong to three classes: those suited for the Chinese, Arab, and the European markets.
>
> The trade in Cambay stones at present (1878) supports about 600 families of skilled workmen, and from 500 to 600 unskilled labourers... Each process is carried on in a distinct workshop under a *kārkhānāwālā* or head of the factory. In each branch of the craft, the heads of factories form a distinct guild or panchayat. The *akikia*, or the agate-dealer must be a man of some capital to buy the incoming rough stones, process them and pass on the finished articles to the agate merchants of Bombay, and through them to Calcutta, China or Jedda.

Ratanpur in the territory of the Raja of Rajpipla has been the centre of the 2000 years old (may be older) international trade in articles made of agate and carnelian.

Corundum, Ruby and Sapphire

Valentine Ball[14] (chap. 9) gave a fairly detailed account of aluminium-containing gem minerals as found and used in pre-modern India. Corundum, when pure, is sesquioxide of aluminium (Al_2O_3) containing traces of lime, silica and magnesia. It is next to diamond in hardness, and widely known as emery (abrasive) in granular form. Typical interstitial and lattice-replacing atoms make corundum red, when it is known as 'ruby', and blue, when it is called 'sapphire'.

It is well-accepted that the use of white corundum started in India. Even the name is derived from the Sanskrit word *kuruvinda*. The British travellers of the early nineteenth century reported indigenous mining works on corundum in India. Captain Newbold, for example, found in the 1840s widespread corundum mining in district Salem—at Caranel, Anpore, Mallapollaye, and at other places up the river Kaveri, as far as Coacorambadi, 'where it had been dug up in the fields, and the remains of the excavations were still to be traced'. Newbold also described the mines at Golhushully and Kulkairi in Mysore (*J. Royal Asiat. Soc.*, vol. VII, pp. 219-24). The corundum occurred in both crystalline and amorphous forms in more or less decomposed talcose schists. The material mined from shallow pits was separated into four classes: red, white, scraps of both, and the refuse. The first three were conveyed to Mangalore and Tellicherry and were sold to Bombay and Arab merchants for Rs. 12-30 per *kandy* (= 500 lbs?) according to quality. These mines had been opened in 1829.

The stone known as *kurund* used to be mined during the 1850s in the upper parts of district Godavari, specially near Bhadrachalam. The first mention of the occurrence of corundum at Pipra, Singrowli (lat. 23° 57' and long. 82°44') in the erstwhile Rewah State was made by Francis Buchanan Hamilton (*Edin. Phil. J.*, vol. II, p. 305, 1820). He had been prevented from visiting the mine in 1814. Captain W.S. Sherwill's report in 1845 (*J. Asiat. Soc. Beng.*, vol. XIV, Proc., p. 15) indicated that the material at Pipra was of six varieties: *gulabi* (rose coloured), *massuria* (like massur dal, pea or lentil), *bhaka* (of varied colours), *telia* (colour of *teli* seeds), mica-mixed, and fibrolite-mixed. In his papers (*Rec. Geol. Sur. India*, vol. V, p. 20, 1872 & vol. VI, p. 43, 1873), F.R.

Mallet published accounts of his visit to this mine situated on a hill between Pipra and Kadopani. Several yards (at places 30 yards) thick reddish gray bed of corundum rested between quartz schist and porphyritic gneiss with hornblende rock. Traceable for about half a mile, the deposit appeared to be 'practically inexhaustible'. Considerable amount of pre-modern mining must have taken place before 1814, and was still going on in 1871.

Holland described[16] the Indian lapidary (*begri*) using different kinds of discs (sān) for cutting precious stones. The corundum-sān or lapidaries' wheel, as used in nineteenth-century India, was composed of about two-thirds of finely crushed corundum cemented with one-third of lac resin. Corundum discs of different grades were used for rough cutting of minerals softer than diamonds, while the polishing was done on discs of bell-metal or pewter. Besides the ordinary *begri* or lapidary, there were men whose business was to bore holes through precious stones, and they were known as *bidhiya.* W. Hoey made a comprehensive report in 1880 on the trade and manufactures of gemstones, including rubies and sapphires.

Rubies were reported in district Salem and along the Mahanadi river between Cuttack and Sambalpur, but most materials came from upper Burma—places like Kyatpyen, 70 miles north-east of Mandalay. Sri Lanka provided most of the sapphires. Many of the famous rubies known in Europe could be recognized to be of Indian origin on account of the way they are pierced through the middle. One such huge specimen acquired in 1367 is now placed in front of the crown of the British queen.[16] Similarly, one Indian sapphire weighing 225 carats was brought to England in 1856.

One 563-carat 'Star Sapphire of India' is displayed in the American Museum of Natural History, New York. The Smithsonian Institution in Washington possesses the 'Star of Bombay' corundum, 'Bismarck Sapphire' of Sri Lanka and the Roser Reeves Collection of ruby gems.

Writing sometime in the middle of the seventeenth century, Nicols mentioned that zircon gems were found in Cananor and Cambay in India.[17] The alluvium at Ellora contained large obtuse octahedron crystals of zircon along with corundum, and these (Sanskrit, *gomed,* red ones known as hyacinth) must have been utilized by the jewellers of Cambay.

Garnet jewels were also popular in India. Voysey, Newbold and others reported recovery of garnets from the Mahanadi bed in Orissa, Kondapilli (lat. 16°38', long. 80°36') in district Godavari, Gharibpeth, 8 miles south of Paloncha, in Hyderabad, etc. There were extensive mines of garnet in the Kishengarh state of Rajputana near Sarwar (lat. 26°4', long. 75°4'30"), from which large-size gems of good colour were obtained, and the Raja derived a large revenue. Ball reported:

> For a distance of about a mile, the outcrop has been burrowed into. It is believed that the large polished garnets cut *en cabuchon* which are available for sale in the principal towns of Punjab, have been obtained in these mines[14] (p. 523).

The mining and widespread trade of beryl in India, ever since the days of Pāṇini, has been discussed elsewhere.[3] When the Britishers came to India, they found that the mines had been nearly exhausted. Clarke reported on Mysore beryls (*Madras J. Lit. & Sci.*, vol. IX, p. 121, 1839), and Capt. Newbold wrote on Coimbatore deposits (*Edin. Phil. J.*, 1840). The Paddoor mine in Coimbatore had been worked for two years in 1818 by one Mr Heath; when Newbold visited, the mining had ceased. The rock there is a vein or dyke of coarse granite consisting of quartz, garnet, mica, etc.; the cavities in cleavlandite feldspar contained beryl crystals. Newbold also alluded to a report that beryl used to be mined at Vaniambadi, at the northern base of the Nilgiris.

Aquamarine crystals from Kangiam in Coimbatore were exhibited at the Vienna exhibition, during the middle of the nineteenth century. There are reports that, by the end of the twentieth century, aquamarine crystals may be recovered from the detrital deposits on the banks of the Mahanadi in Orissa.

Diamonds

Let us now pass on to the most outstanding gem mineral that India ever produced: diamonds. C. Ritter in his *Erdkunde von Asien* (vol. IV. pt. 2. p. 343, 1836) collected together the various scattered reports on Indian diamonds, and Valentine Ball provided a more exhaustive account of the diamond works in pre-modern India[14] (pp. 1-50).

C. Ritter arranged the Indian diamond mines known to him in five groups, in order from south to north:

1. The *Cuddapah* group on the Penner river including the ancient mines of Condapetta, Munimadagu, Wajra Karur, etc.
2. The *Nandial* group between the Penner and the Krishna rivers including the mines of Banaganapalli, Ramulkota, etc.
3. The *Ellore* or *Golconda* group on the Krishna, which included the famous mines of Kollur, Partial, Muleli or Malavilly.
4. The *Sambalpur* group on the Mahanadi river, which included Tavernier's Sumelpur or Semah/Semul on the North Koel river as well as Wairagarh of the Central Provinces.
5. The *Panna* group in Bundelkhand.

Bauer's map of ancient diamond fields of India[18] is reproduced in Fig. 1. We would discuss diamond mining in pre-modern India from a chronological point of view and on the basis of literary and archaeological evidences. Bauer commented[18] that the working of the most important diamond deposits in India 'date back not to very remote periods, probably in all cases subsequent to the year AD 1000 and sometimes much later'. Though we do not have specific C-14 dates, we disagree with Bauer on the basis of literary records. The currently known diamond fields in India are also shown in Fig. 1.

Kauṭilya's *Arthaśāstra* of the late fourth century BC was probably the first text to describe the Indian diamond or *vajra* and the mode and area of its occurrence (2.11.37-41). The mine and stream deposits were listed as their sources.

It is hard to identify the precise locations of the place names mentioned in *Arthaśāstra, Bṛhatsaṁhitā, Ratnaparīkṣā, Agastimata,* etc. in regard to the diamond fields, but we may conjecture the following locations : Wairagadh (ancient Vajragṛha) 80 miles south-east of Nagpur on the Sath river, a tributary of Weinganga (Vena Ganga of the *Bṛhatsaṁhitā*); the Kośala region of Ākarāvanti around the famous Panna in Madhya Pradesh; the region around the Golconda mines, formerly known as Mātanga; the Paunda or the Chota Nagpur area around Soumelpur; the Kalinga alluvial resources from the Mahanadi valley; the Sambalpur district; the Koel river; Hīrākuṇḍa (literally 'diamond mine'), etc. Diamond-washing has been traditionally done by the tribes of *Śavara* (Sambalpur area), *Kol* (Chota Nagpur), *Goṇḍa* (Madhya Pradesh), etc. Ptolemy had mentioned the country of the Śavaras and Sambalaka (Soumelpur) and of Mandalai (Mundas) as the sources of Manada (Mahanadi).

Decline in Diamond Trade

Valentine Ball asserted[14] (p. 48) that there was no real exhaustion of the localities where diamond mining was possible. On the contrary, the diamond beds extended far more than the ancient miners ever supposed. They acted on chance discoveries and rule of thumb knowledge. That they systematized their observations about the diamond-bearing strata and applied them to distant tracts is extremely doubtful. There is no evidence that any intercourse or communication took place between the workers at distant localities. Ball hoped that scientific guidance would improve diamond production in India.

Dutt[19] attributed various reasons to the decline of Indian diamond industry: exhaustion of diamond-bearing rocks, water trouble in the excavations, oppressive nature of mining and political administration, absence of systematic prospecting operations, superstitions amongst the workers, and discovery of diamond fields in other parts of the world. India lost its monopoly in diamond trade in 1728 when the Brazilian mines began to be exploited. In 1870 the South African mines monopolized the global markets in this precious gem.

Summing Up

The pre-modern Indian traditions in gem production were doomed to extinction in view of inefficient technology and management, which also plagued the non-gem mineral and metallurgical industries. Thus, the comments made by Ball[14] (p. 48) and Dutt[19] on ancient diamond mining in India have general applicability. The common issues may be discussed later in a broader framework.

Our present discussion on gem minerals in pre-modern India indicates a remarkable continuity in traditions from the sixth to the end of the eighteenth century. This had been adequately testified by the Arab, Persian and European travellers. The British travellers and scientists of eighteenth and nineteenth centuries witnessed pre-modern technologies in mining and processing of gem minerals and left detailed accounts, which were brilliantly summed up by Valentine Ball.[14]

The Sanskrit words for gem minerals, culled from *Ratnaśāstra* and *Rasaśāstra* texts, were compiled and tabulated by the present author.[1] Some of the Arabic/Persian words used in medieval India and their approximate or likely English equivalents[16,20,21] are listed in Table 1.

Mining and processing of gem minerals was primarily done for the affluent class of the Indian society and the outside world. For a low quantum of output, a very large number of the poor worked under appalling conditions. Technological levels were primitive and almost no attempt was made to upgrade them. Interactions between workers of different trade guilds, and between workers and intellectuals were negligible. The scholars of the *Ratnaśāstra* and the Muslim gemmological texts hardly advanced their earlier knowledge on the subject. Yet, in spite of apathetic working conditions, the ill-paid and ill-fed Indian workers toiled in the mines and produced exquisite art jewelleries for the whole world to marvel at.

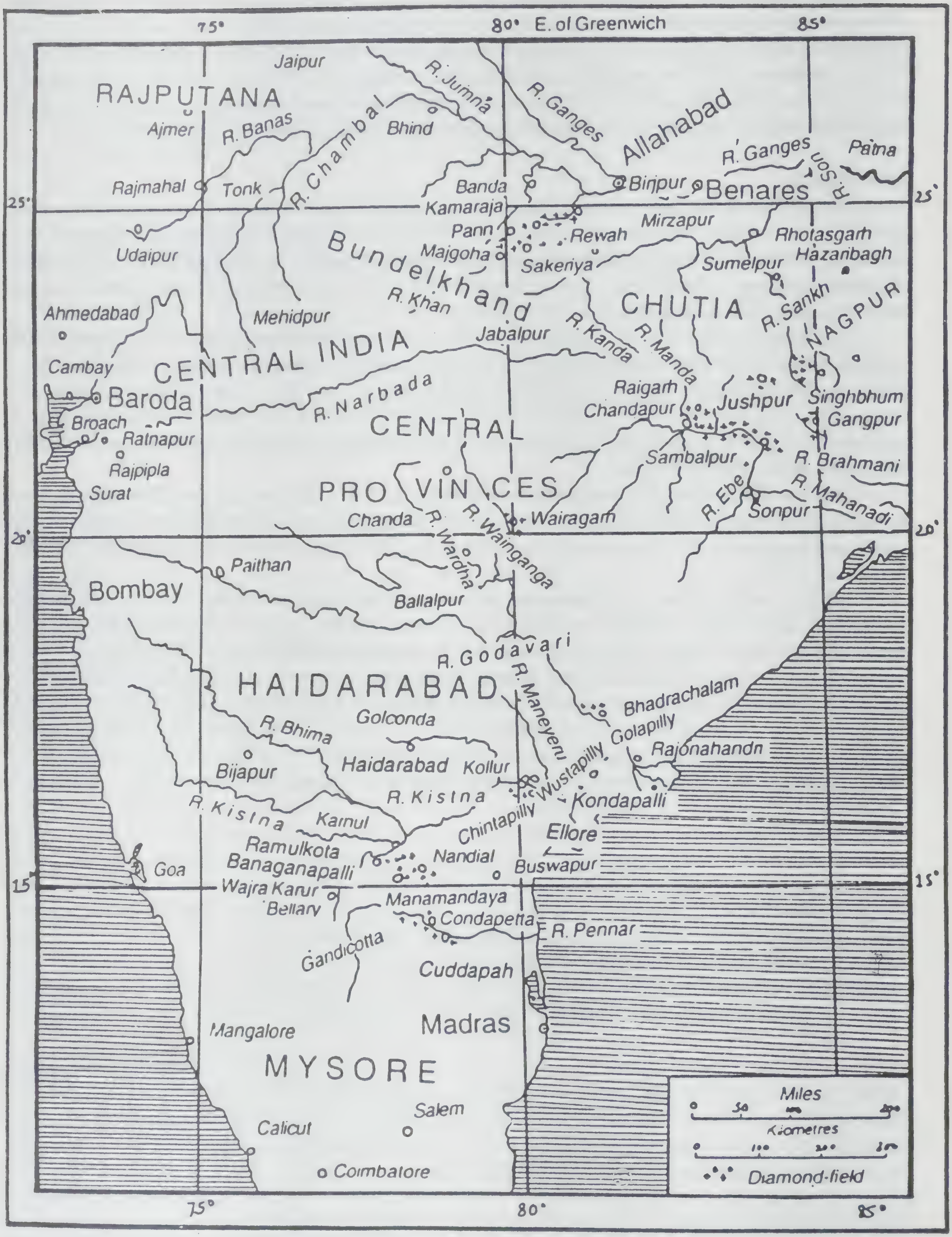
75°
80° E. of Greenwich
85°
RAJPUTANA
Jaipur
Ajmer
R. Banas
R. Chambal
Bhind
R. Jumna
R. Ganges
Allahabad
R. Ganges
Patna
R. Son
Rajmahal
Tonk
Banda
Birjpur
Benares
Kamaraja
Pann
Rewah
Mirzapur
Rhotasgarh
Udaipur
Majgoha
Sakeriya
Sumelpur
Hazaribagh
Bundelkhand
R. Khan
R. Sankh
Ahmedabad
Mehidpur
CHUTIA
NAGPUR
R. Kanda
R. Manda
Jabalpur
CENTRAL INDIA
Cambay
Baroda
R. Narbada
Raigarh
Jushpur
Singhbhum
Chandapur
Gangpur
Broach
Ratnapur
CENTRAL
Rajpipla
Sambalpur
R. Brahmani
Surat
PROVINCES
R. Mahanadi
R. Ebe
Sonpur
Chanda
R. Wardha
R. Wainganga
Wairagarh
25°
20°
15°
Paithan
Bombay
Ballalpur
R. Godavari
HAIDARABAD
R. Maneyeru
Bhadrachalam
Golapilly
Golconda
R. Bhima
Wustapilly
Rajonahandri
Bijapur
Haidarabad
Kollur
R. Kistna
Kondapalli
R. Kistna
Karnul
Chintapilly
Ellore
Ramulkota
Nandial
Banaganapalli
Buswapur
Goa
Wajra Karur
Bellary
Manamandaya
Condapetta
R. Pennar
Gandicotta
Cuddapah
Madras
Mangalore
MYSORE
Salem
Calicut
Coimbatore
Miles
0 50 100 200
Kilometres
0 100 200 300
Diamond-field
75°
80°
85°

Fig. 1. *The Diamond Fields of India* (taken from Bauer)[18]

Table 1: *Some Persian, Arabic and Hindustani Terms Regarding Gem Minerals Used In Pre-Modern India* (taken from Holland[16], Prinsep[20] and Tagore[21])

Terms	*Meanings/Remarks*
ABU-IS ‘HAQI	Father of Isaac or ‘genuine’ turquoise, product of Nishapur in Khorasan, discoloured by heating; probably *calaite* variety of turquoise containing 18% water
AKĪK	Agate (also carnelian in Yemen)
AKĪKIYA	Gem cutter and polisher
A‘LMĀSH	Also Almās or diamond; see MĀSH
ĀYN-UL-HIREH	Cat’s eye, chatoyant sapphire
BADAKSHĀNI	Turquoise different from Abu-Is’ haqi or Nishapuri variety; withstands heat or fire without alteration; could be odontolite or bone turquoise; Badakshāni ruby is same as Balas-ruby
BASUD	Coral-like porous material devoid of gelatinous mass, available in Yemen, Maldives sea-water
BAWA GHORI	Onyx
BEGRI	Lapidary
BELLĀOR/BELLOR/BILHAUR	See BILOR
BERŪJ	Beryl from *Vaidūrya* (Sanskrit)
BIDHIYĀ	Who bores holes through precious stones
BILOR	Rock crystal
CHESHAMDAR	Quartz cat’s eye; also Dola
CHUṆĪ	Ruby weighing less than one *rati*
DOLA	Quartz cat’s eye
DSCHEMST	Amethyst
EBRENDSHE	Gold marcasite
FEROZĀ/FIROZEH/FIRUSE/PEROJ	Turquoise; also see ABU- IS’ HAQI and Badakshani
GULĀBĪ	Rose-coloured corundum from Rewah
HAKIK	Agate; see AKĪK
HUKKĀK	Cutters and polishers of gems
HUZUR	Gem (Arabic)
ILMAS	Actually A’lmāsh or diamond
JASCHEP	Jasper
JAUHAR/JAWĀHIR/JAWHAR	Jewel
JUZĀ	Cat’s eye found in the mines of Akīk or agate
KAMĀNĪ	A bow used for working a gimlet in gemstone boring (Hindustani)
KASH	From *Yu she,* Chinese for jade which comes from eastern Turkistan; hence the name of the place is Kashgarh
KORUND/KŪRŪN	Corundum from *Kuruvinda* (Sanskrit)
LĀJBURUD/LĀJAWARD	Blue lapis lazuli; in Sanskrit *rājāvarta*
LĀL	Red-coloured balas or spinel ruby
LĀL-BADAKSHANI	Rose-coloured ruby of Badakshan, capital of Balkh; Balas-ruby, *Bālasūryaka* in *Arthaśastra*
LĀL-MINA	Violet-coloured almandine ruby
LĀL-PIAZI	Onion-coloured, reddish yellow ruby
LĀL-PUN NĪLA	Sapphire with a tinge of red

Terms	*Meanings/Remarks*
LĀL-RUMANI	Scarlet or pomegranate coloured ruby, usually from Burma
LULU	Pearl (Arabic)
MANAK/MĀNIK	Ruby weighing over one *rati*; see also CHUNI
MARK-I-SHĪSĀ	Marcasite or iron pyrite
MAROWARIT/ MERWARID	Margarita or pearl
MĀSH	Diamond (Arabic)
MORA	Onyx
MURJĀN	Coral, best variety Mugā
NĪLĀ	Sapphire (blue)
PITONIĀ	Helioptrope or bloodstone which is green gem (plasma) interspersed with dot of red
POKHRĀJ/ PUKHRĀJ	Topaz
RAG-Ī-LĀL	Vein of rubies
SANE	Corundum wheel or stone-cutting wheel, also for polishing gems and sharpening tools
SANGTARĀSH	Stone-cutter
SARD	Sardonyx
SENBADE	Corundum
SITAREI SEMIN	Star of the Earth or talc
SONELĀ	An inferior variety of topaz (golden)
SUABHAJI	Moss agate
SUBJ-PUN NĪLA	Sapphire with a tinge of green
SUNG	Gemstone (Persian)
TĀBLĀ	Cut rubies (Burmese)
TANJĪN	Polished rubies (Burmese)
TORĀ	Yellowish beryl
TURMALI	A kind of Yakut, possibly tourmaline, could also represent zircon, hyacinth, etc.
UPUL	Opal (many coloured)
YĀKŪT/YĀQŪT	Hard gem minerals like ruby, sapphire, etc. a generic name
YĀKŪT-AHMAR	Oriental ruby: *arghwānī* (hyacinth); *khamrī* (red-wine coloured, amethyst); *khylī* (asafoetida-coloured); *lahmī* (flesh coloured); *mihrmātī* (striped); *rūī* (brass coloured)
YĀKŪT-ARZAQ OR QABŪD	Sapphire, *nīlā; taüsi* (peacock-tail); *nīlī* (indigo)
YĀKŪT-ASFAR OR ZARD	Topaz, *pokhrāj*, *narinjī* (orange); *turanjī* (citron coloured)
YĀKŪT-RUMĀNĪ	Bright red ruby
YĀKŪT-SURKH	Amethyst or topaz (Gladwin)
ZABARJAD/ ZUBURZUD	Beryl, green aquamarine; also confused with yellow chryso-beryl and topaz
ZAFFRE	Cobalt sulphide used for painting of glass and porcelain
ZAHĀBĪ	Gold coloured or yellow beryl
ZAMARŪD/ ZUMĀRRŪD	Emerald, green crystalline

III. NON-GEM MINERALS IN PRE-MODERN INDIA

As a sequel to our comprehensive report on minerals and metals in ancient India,[1] we submit here a tentative account of the non-gem minerals in India during the Muslim period, better styled as 'pre-modern' India.

We would mainly record the nineteenth century account of the British travellers and geologists who looked backwards and performed the role of historians. Before we proceed with itemized discussions on salt, *reh*, and the metallic ore deposits, let us emphasize the severe paucity of chronological data on the subject.

The early Muslim world could collect sufficient information on Hindu medicine, astronomy and mathematics, but very little about Indian mineral resources. Abu Raihan Al-Beruni (AD 973-1048) was acquainted with the properties of gems and minerals; he even measured their specific gravities. But he failed to gain any insight into Indian alchemy based on the mineralogical method, because the Indians kept the information concealed.

Irfan Habib wrote: 'The Delhi sultanate lacks any description of its economic resources of the kind that Abul Fazl supplies for the Mughal empire; only a very incomplete sketch can therefore be offered of its mineral and craft production.'[22]

Even though the Salt Range mines in Punjab were mentioned by Yuan Chwang, there was no further mention about these during the Muslim period before Abul Fazl's writings in 1595. The Sambhar lake salt was however mentioned[22] by Minhaj Siraj in 1259.

The paucity of data during the Muslim period was partly due to the widespread secrecy adopted by the vanquished Hindu people who refused to accept Muslim domination as a settled fact. As late as 1595, Abul Fazl admitted the ignorance of the Mughal rulers regarding the zinc ore processing technology which had been operating for many centuries in Zawar (near Udaipur), Rajasthan. Even the European travellers, meticulous in their writings, often found the veil of secrecy difficult to pierce.

The Muslim rulers could gain access to the local mineral resources and indigenous technology only gradually, and with considerable difficulty. Thakkura Pherū, born sometime during the end of the thirteenth century, was a Jaina scholar as well as an assay-master in Alauddin's court. He wrote in his *Dhātutpattiḥ,* how the copper ore from Babera (Babai, 8 miles south of Khetri) could be reduced to the metallic state. Pherū also wrote[23] about ores of lead, tin, mercury, cinnabar, realgar, orpiment, cementation brass, etc., but not about reduction-distillation of zinc which was going on at Zawar and was mentioned in the contemporary account of *Rasa-Ratna-Samuccaya.*

Pherū mentioned[23] gold being obtained from river bed washings and not any sub-surface mine. Gwalior iron ore was one of the surface mine products which was exploited to produce iron and steel, right from the days of king Bhoja of Dhar, Malwa, to the Sultanate and Mughal periods. Marco Polo and other travellers described pearl fishing and diamond mining in the south.

References to mineral production in India are only slightly more during the Mughal period. Abul Fazl mentioned about gem minerals but not their sources; casual references are there in his *Ain-i-Akbari*[24] about metalliferrous ores producing metals like iron, copper, lead, tin, bronze and brass, also salt works of Punjab and saltpetre. The last one, in the words of Abul Fazl, 'produces the explosive heat in gunpowder and used by his Majesty (Akbar) as a means for cooling water'. It was the former use of saltpetre which attracted the attention of the western colonial powers who started importing the material from India in the beginning of the seventeenth century.

The extensive trade of Indian saltpetre for several centuries, reported[25] by Moreland, is hardly mentioned in any Indian writing. Similarly the diamond production in India and its trade are subjects to be gleaned only from the accounts of the European travellers. Finally, the eighteenth and nineteenth century visitors and geologists from England left accurate written accounts on minerals in India which have been beautifully summarized by Valentine Ball.[14] We would quote their reports on the ancient workings only, leaving out the references to the 'fresh discoveries' of mineral deposits in the nineteenth century, which are not relevant for our purpose.

Salt in India

Valentine Ball wrote that 'there are several very distinct sources of salt in India, each of which is practically inexhaustible'.[14] He referred to many coastal areas where salt must have been obtained since time immemorial by the evaporation of sea-water. Specific sites on Madras, Orissa, Bengal and Bombay coasts were mentioned. In district Chingleput, for example, manufacture by solar evaporation in pans started in January as soon as the rains were over. The process of evaporation was continued for about a month. Complete evaporation was avoided to leave out magnesium sulphate and the hygroscopic salts in solution. Backwater and saline earth were widely exploited in India for recovery of salt, but these practices were often legislated against by successive rulers.

Al-Beruni had made a remarkable postulate that a large portion of India had at one time (in the early geological era) been under the sea. The British geologists confirmed this postulate by citing the examples of saline lakes in Rajasthan and salt ranges in the north-western part of the subcontinent. Eliot wrote in 1880:

> The whole country of India, from Jhelum to the Afghan frontier is full of salt, and is constantly mentioned by English writers from comparatively early times.[26]

The Sambhar lake is situated on the eastern side of the Aravalli range in Rajasthan, on the borders of two erstwhile princely States—Jaipur and Jodhpur. Its greatest length is 20 miles, and average breadth 5 miles. Its greatest depth being 3 ft, this lake is merely a hollow in the midst of long ridges of sand. The high salinity (never less than that of sea-water, even during the rains, sp. gr. being 1.03 at that time) after February (sp. gr. exceeding 1.20) results in deposition of salt. In hotter weather, the deposit presents 'a dazzling roseate-white efflorescence with blue, white and red crystals'. Left in the sun, there is some hardening of the deposit and the reddish hue is lost.

We have earlier referred to Minhaj Siraj writing on Sambhar lake salt in 1259. Production and distribution of salt were taxed and levied throughout the Muslim period. During the British period also, this mineral was often the bone of contention between the ruler and the ruled. Between 1856 and 1873 the Sambhar lake produced on an average 25,000 tons of salt per year, which was distributed to other areas by bullock-carts and camel-carts. In 1879, the production shot up to over 1 lakh tons, partly on account of British management and partly due to the heroic efforts of the Rajputana State Railway, which was asked to, but could not handle an even larger tonnage! Ram Singh, the Maharaja of Jaipur, requested the then Viceroy not to take away from him a part of his salt-revenue: 'Please do not mention the word salt!'[26]

Salt Reserves in Punjab

The province of Punjab in pre-partition India possessed enormous deposits of rock salt; the region still does. In the trans-Indus region there are deposits in Kohat, and there are also deposits close to Kalabagh, the latter being merely a continuation of those in the cis-Indus salt-range, geologically much more ancient than the Kohat salt. A report on these deposits and their ancient workings was provided by A.B. Wynne and Dr Warth (*Memoirs of Geological Survey of India,* vol. XI, p. 299; vol. XIV, pp. 274-84) and quoted by V. Ball.[14]

The Kohat district area of 60,000 square miles was estimated to possess over 40 million *maunds* of salt. In this region, the salt used to be obtained by open quarrying, and not by mining as in the salt ranges. The principal quarries were at Malgin ('worked from time immemorial'), at Bhadur Khel ('opened twelve centuries ago'), and at Jatta opened in the year AD 1650. Yuan Chwang's reference to Punjab salt mining could have been with reference to Malgin, Bhadur Khel or the cis-Indus salt range itself. Jatta was developed during the closing years of Shah Jehan's rule. The Sikh control of some of the mines started during the latter half of the eighteenth century.

At Malgin, the salt cropped out for a distance of 3 miles. The quarries at Bhadur Khel were 4 miles in length and about half a mile in breadth. At Bhadur Khel as well as at Kurruk, the salt used to be obtained in 13"x13"x4" (thick) slabs (called tubbs), detached from the rock by pickaxes and wedges utilizing the natural stratification in the rock.

The salt range mines like those near Pind-Dādan-Khān, about 100 miles north-west of Lahore, were exploited for centuries. Akbar was informed about this range by one Asp Khan.[27] One Mir Abul Qasim was assigned by Akbar to administer the 20 *kos* long *namaksār* or salt range; he was known as *namakīn*.[28] The merchants paid to the miners a maximum $^1/_{20}$th of a rupee per *man* of salt, and about the same amount for government levy, and sold the salt in the Lahore market at about $^3/_8$th of a rupee per *man*.

Ancient Sikh period workings were found at Khewra (subsequently expanded as Mayo mines) Varcha, Jutana, Sardi, Makrach and several other areas. Lieutenant Burnes visited the mine at Keoru, five miles from Pindi-Dadan-Khan and left an interesting account (*J. Asiat. Soc. Bengal*, April, 1832, pp. 145-8):

> We entered a cavern of irregular dimensions. The cavity has been exavated from the roof downwards. The salt is hard and brittle, so that it splinters when struck with the sledge-hammer and pickaxe. The rock is never blasted with gun-powder, from fear of the roof falling in; and accidents of this kind sometimes happen in the present simple mode of excavation. The mines are not worked for two months during the rains for the same reason. The miners live in villages among the hills. They receive a rupee for every 20 maunds of salt brought to the surface. The salt is not pure, having a considerable mixture of some substance (probably magnesia).
>
> 2500 *maunds* (1 *maund* equalling 100 English pounds) of salt are extracted daily, which gives about 8 lacs of maunds for the year. The price has gone up from a quarter of a rupee to two rupees per *maund*, exclusive of duties.
>
> It is closely monoplized by the Panjab (Sikh) Government, and Ranjit Singh hopes to derive an annual revenue of 16 lacs of rupees with 2 1/2 (lacs) additional for the duties. 1 1/2 lakh of rupees is expended in working the mineral. The profits amount to about 1100 per cent, though the salt is sold for one-third the price of that of Bengal, which averages 5 rupees per *maund* of 80 lbs.

Eleven years later (1843), one Dr Jameson visited the old Jutana mines, which had been operating for 20-35 years. The descent into the mine was by steps cut in the salt, and the workings seemed to have been large, but as irregular as was usual in Sikh excavations. The old workers at Varcha and elsewhere left the roof unsupported, which caused a lot of roof-collapse. When the British experts like Dr Warth took over, appropriate supports were provided in the modernized mines (as in Khewra, renamed Mayo) to take care of 'the dangerous chambers left by the old Sikh workmen'.

While modernizing the salt industry in India, the British rulers followed the Muslim, Maratha and Sikh rulers in controlling the salt trade and revenues, their actions being often prejudicial to the interests of the common man.

Alkaline Salt, Reh in India

Reh is the Indian term applied to efflorescent salts which have accumulated in the soil and in sub-soil waters of large tracts in India, often to such an extent that cultivation has become impossible. However, the alkaline constituents of *reh,* sodium carbonate and bicarbonate (apart from variable proportions of chloride and sulphate), have aided ancient and pre-modern civilizations in making glazed potteries (e.g. NBPW), glass, soap, bleaching recipes, medical formulations, and in washing, dyeing, and curing of hides in tanneries.

The efflorescent salt deposits have been variously known as *reh* in Uttar Pradesh, *khari* in Bihar, *kallar* in Panjab, *dalla* (red) and *papadi* (white) in Vidarbha region, *chavudu* in Andhra Pradesh, etc. *Saji matti* is the name of the marketed crude mixture of sodium salts lixiviated out of *reh* and concentrated. Typical compositions of *reh, saji matti* and salt lake bittern are provided in Table 2.

Table 2: *Typical Compositions of Reh, Saji Matti and Bittern*
(taken from La Touche *et al,*[29] Auden *et al*[30] and Brown & Dey[31])

Location Material	*Moradabad Reh*	*Meerut Reh*	*Kanpur Saji Matti*	*Sambhar Lake Bittern*	*Lonar Lake Incrustation*
Composition (%)					
Na_2CO_3	9.66	4.68	27.02	14.5	8.2 - 33.2
$NaHCO_3$	8.55	3.96	4.28	9.1	6.3 - 24.4
$NaCl$	1.92	3.88	—	28.6	28.0 (av.)
Na_2SO_4	8.66	1.19	33.98	40.5	2.0 (av.)
K_2O	—	—	—	—	4.3 - 10.3

Auden *et al* estimated[30] that the *reh*-infested districts of Uttar Pradesh alone produced 0.5 m-ton Na_2CO_3, 0.6 m-ton $NaHCO_3$ and 0.3 m-ton Na_2SO_4. Similar data from other states have been compiled[31] by Brown and Dey, but these are twentieth century data which do not concern us. However, these data do illustrate the possible extensive use of the naturally occurring materials in pre-modern India, for which some information was collected and is presented below.

Dr Heyne mentioned in his *Tracts* (p. 45) that among the Chitaldrug hills in Karnataka, an abundant commodity called *sabboo,* a mixture of sodium carbonate and sodium chloride, was sold in the local market. Captain Campbell noted similar material in district Salem being recovered, from the soil resting upon *kankar,* by a simple process of lixiviation and evaporation. The Lonar lake in Berar (Vidarbha) was noted by Captain Mackenzie (*Berar Gazetteer,* p. 24) to be a crater-like hollow, more than a mile in diameter. The deposited salts (the range of analytical values provided in Table 2) used to be raked up by divers and sold as *dalla* (red, more of carbonate and bicarbonate) at Rs 75-125 per *kandy* (500 lbs?) and *papadi* or *papri* (white, more of chloride) at only Rs 18-25.[32]

In 1832, R. Everest reported the deposits of salt efflorescing on the surface in district Bharatpur and Bundelkhand country, which were being scraped off and used by the local inhabitants (*J. Asiat. Soc. Bengal,* April 1832, pp. 149-50). The material consisted of sodium chloride, carbonate and sulphate. In 1834, J.S. Burt described 'the mode of extracting salt from the damp sand-beds of the River Jamuna as practised by the inhabitants of Bundelkhand' (*J. Asiat. Soc. Bengal,* January 1834, pp. 33-6). Burt found a process of lixiviation of the *phultā* (swelling-up) sand in operation on the Jamuna river bed 24 miles from Kalpi. After lixiviation, the salt extract was boiled in earthen pots until it evaporated leaving behind a salt at the bottom. From 80 lbs of sand about 1 lb of salt was obtained. The unrefined salt was sold at Re 1 per *maund* of 40 *seers* or 80 lbs. Burt also noticed people living on the Ganges at Kanpur scraping the ground up to half an inch and extracting the salt by lixiviation.

J. Stephenson reported (*J. Asiat. Soc. Bengal,* January 1834, pp. 36-7) from Ghazipur that the salt there contained not only sodium chloride, sulphate and carbonate but also nitrate of potash and lime. In the village of Ratouly there was a thick layer of *kankar* impregnated with a large proportion of saline matter, chiefly chloride, sulphate and carbonate of sodium. The formation of such a porportion of saline matter was presumably on account of evaporation and interaction (with limestone in *kankar*) of the subsurface and seepage water. The famous French chemist Berthollet provided similar postulates for the formation of Natron lakes around the river beds of Egypt.

Borax or hydrous sodium bi-borate also occurs as an exudation on the surface of saline soils, and often in connection with salt lakes and associated with sodium chloride and sulphate. It was widely known and used in the ancient world: as *tankana* in Sanskrit, *tshale* in Tibetan and *tinkal* in the western world. India's main supply was from the hot springs in the Puga (or Pugha) valley of Kashmir (known as *sohāgā*) and Gnari or Hundes and the series of lakes like Chapakni, Rudokh and Tengri-Nur in Tibet. Ball quoted E.T. Atkinson describing the Tibetan process for extraction of borax.[33] After lixiviation and evaporation, the crude borax was further refined by pounding, removal of impurities in lime-water, filtration, dissolution in boiling water, followed by evaporation and crystallization in *kānsā* (alloy of copper, zinc and lead) vessels. There are Dutch records of 1618-19, 1625, etc. which show export of Indian borax from Masulipatam.

Limited space does not permit us to give details about our findings on saltpetre and *sehtā* or ferro-cobaltite in pre-modern India, which have been reported elsewhere.[34] We have also reported therein exploitation of copper-, iron-, and aluminium-sulphate deposits in medieval India.

IV. METALLIC ORES AND METALS

As regards raw materials yielding useful metals, we have surveyed river sand washing for recovery of gold, iron ore mines, the centuries old tradition of copper ore mining, and dating of some of these mines.[34] We present below some selected information on zinc and lead in medieval India.

Zinc in Medieval India

One of the most spectacular achievements of pre-modern India in the field of metallurgy was in respect of zinc. We have discussed the primacy of India in ancient brass and zinc metallurgy elsewhere.[2] A very startling fact was that the vast information on the subject was unknown to us until, in the 1980s, several scholars like Willies, Craddock, Hegde, the present author, etc. unearthed the same through field, laboratory- and literature investigations.

Lynn Willies of Peak District Mining Museum in England investigated and reported on three areas of ancient mining in Rajasthan—Rajpura-Dariba, Rampura-Agucha and Zawar—relating to zinc-lead-silver ores.[35,36] There are evidences that these three metals were extracted from the ores in ancient India. Mining started in Zawar (near Udaipur) in the fourth century BC (C-14 dating), if not earlier, and went on for several centuries.

There was a boost in mining and metallurgy of zinc and lead in Zawar around the thirteenth century AD, and this went on for another five centuries. The Hindu rulers of Udaipur area managed to keep their technology secret. Neither the Muslim nor the British rulers could gain access to the technical knowhow. Thus, Abul Fazl in 1595, Tod in 1829, Brooke in 1850 and even Valentine Ball[14] in 1881 could scarcely throw light on the well-guarded secrets of the Zawar mines. On account of famine and Maratha invasions, mining and smelting stopped around 1812.

The host rock of the Zawar mines was sheared dolomite. Within the beds, zinc occured as sphalerite or as marmatite, in which ZnS was in solid solution with iron sulphide. Also associated with the rock were galena, hydrozincite, pyrite, silver, etc.

One of the mines investigated by Willies[35] was of commodious proportions—Pratapkhan or Pratap's mine, in which Rana Pratap Singh, rival of Akbar, took refuge during AD 1595-1600. The mining system had adequate timber work, fire-setting facilities, mining tools, pitchers for manual dewatering, etc.

Manually picked sphalerite-rich particles were roasted and then reduced in brinjal-shaped retorts; the zinc vapour was condensed as liquid under reducing conditions and collected. Freestone *et al* estimated[37] through the analysis of the residue in the spent retorts (about 6 lakh tons), that nearly one lakh tons of zinc must have been produced during the period thirteenth-seventeenth century. About 6000 tons of zinc metal were still left in the retort residues, which could be recovered by modern technology.[38]

There are also in this area at least 16 deposits of glass slag, totalling 30,000 to 35,000 tons, which are residues after recovery of lead and most possibly silver by the cupellation process. It is well-known that Rajasthan lead-ores are argentiferous; lead concentrate in the modern Zawar plant assays nearly 0.1% silver. The Mughals wanted to overpower the Udaipur territory mainly to have monopoly of trade in zinc, brass, lead and silver.

Lead in Medieval India

There are extensive old workings of copper, lead and zinc ores in the areas of Ambaji (24°20'N, 72°51' E), Gujarat, and Basantagarh and Deri (24°23' N, 72°50' E) in the neighbouring district Siroha in Rajasthan. Large dumps of ancient slag, metallurgical tools, smelted metal and potteries have been found at Ambaji and behind the group of Jain temples in the adjacent Kumbaria (24°19'N, 72°51' E). The metals were used during the pre-Christian era Śunga period and the post-Christian era Kshatrapa period.[39, 40] Lead and silver coins of second-fourth century have been recovered from this area.

C-14 dating indicates extraction of copper, zinc, lead (and possibly silver) during AD 1070-1440 from the Ambamata deposit in Gujarat and Bandlomattu-Agnigundala area in Andhra Pradesh. At Agnigundala, mining was done in the nature of long, open trenches as well as along the dip of lodes reaching a depth of 30 m.[41] The ancient Gavulabhavi lead deposit in district Cuddapah, Andhra Pradesh, was similarly developed through 280 m long surface diggings and underground shafts reaching 50 m below the surface.[42] At Agnigundala, extensive mining, mineral processing (crushing, grinding and beneficiation) and smelting (of copper and lead) took place, which is evident from the rock dumps, slag heaps and appliances like cupolas, crucibles and tube-like bodies, tapering somewhat and closed at one end. A few pieces of lead were found in the heaps assaying 99.5% lead and 220 ppm silver.[41]

Ball testified[43] to the extent of ancient lead mines in southern India, Afghanistan, Baluchistan and Rajasthan. The Zangamrajupalle lead mine (14°46' 30" N, 78°56'30" E) had been described by King and Newbold. King's account (*Mem. GSI*, vol. VIII, p. 273) stated: 'The old and now deserted lead workings are at the south end and east side of the low ridge (near Cuddapah) just north-north east of the village.' Further south and west of the village, there are again numerous old galleries excavated in the same series of beds, from which galena ore had been removed. Captain Newbold described (*J. Royal Asiat. Soc.* vol. VII, 1843, p. 217) having descended a considerable depth into one of a group of over 50 mines. Some of the masses of rock exhibited signs of blasting.

The origins of the extensive excavations in this tract are 'lost in obscurity'. It is believed that these mines were worked by the Hindu kings of Vijayanagara and then the Muslim Nawabs of Cuddapah during the reign of Halim Khan, and later by Hyder Ali and Tipu Sultan. A sample of ore in this area assayed by Mallet in 1879 contained 78% lead and over 22 oz of silver per ton of lead. Dr Balfour was quoted by Ball[14] (p. 232) as saying that the people of Zangamrajupalle in Cuddapah used to 'extract silver from galena by a tedious, clumsy and expensive process in which the lead was all lost'.

In 1846, Captain Newbold described (*J. Asiat. Soc. Bengal,* vol. XV, p. 389) the lead mines in the vicinity of Gazalpalle (15°26' N, 78°45' E). A broad deep trench or quarry cut in these rocks was 'supposed to have been the work of the Mughals'. In recent times, Rao & Rao have mentioned some of these ancient workings.[42]

Some old mines situated near Joga on the Narmada in district Hoshangabad produced mainly lead ore (*Rec. GSI,* vol. XII, p. 174). These were locally known as *Chāndi-kā-Khan* or silver mines. Presumably, silver was obtained from galena. Mallet analysed the silver content to be about 21 ounces per ton of lead.

A tract of country on the banks of the Tons river (north-western Uttar Pradesh), partly included in the Sirmur state and partly in Jaunsar district, neighbouring the site of Swinj (30°43' N, 77°47' E), had many ancient lead mines as surveyed by Captain Herbert in 1826 (*Indian Rev.* vol. II, 1826, p. 349). Near Bhatnor or Barthenole (30°44' N, 77°46' 30" E) the limestone rock was soft permitting galleries to be made in erect position. At Borela in Jaunsar, however, the passages were narrow and tortuous. The quantity of lead ore which had been removed 'must have been enormous, since at Borela alone there were upwards of 80 galleries.' However, the mining industry there dwindled rapidly. Medlicott who visited the locality in 1862 wrote (*Mem. GSI.* vol. III, p. 179) that only one mine was open at that time.

Dr Lord, a medical man, reported in 1837 a wonderful lead ore mine at Feringal (34°45' N, 68°30' E) in Afghanistan: 'the shafts and galleries showed a most surprising degree of mining knowledge' (*J. Asiat. Soc. Bengal,* vol. VII, p. 533). Such mines might have supplied lead to Mughal India. The lead ore mines of Sekran (27°48' N, 66°24' E) in Baluchistan were very extensive but were found deserted in 1877. One had to crawl through the tortuous passages for mining the ore. The vast quantities of slag lying about on the surface testified to the former extent of the industry. Some ore was smelted in simple open furnaces by the Mardui tribe of the Brahuis.

As we have already mentioned, neither the Muslim nor the British rulers were aware of the details regarding mining and smelting at Zawar near Udaipur in Rajasthan. The lead ore technology at the Taragarh Hill (26°28'N, 74' 41' 30" E) close to the city of Ajmer was, however, well-documented by Captain Dixon[44] and quoted by Ball.[45] Dixon visited the mines in 1830 and wrote: 'That they have been in use for a long time, doubtless many centuries, is satisfactorily attested, by the number that are now lying unemployed.'

The ores were of three classes, namely, oxides, carbonates, and sulphides; the last variety, galena, was also used as *surmā* for anointing the eyes. The ore, brought to the surface by the miners, crawling through the tortuous passages, was crushed, ground and washed by hand in conical wooden tubs. The heavy galena particles settling faster were separated, dried and then 'kneaded up with equal weights of cowdung into lumps of the size of a pigeon's egg'. Dixon further stated:

> When dried, it was ready for the furnace, a simple structure of clay, 3 feet high, with an upper internal diameter of 11 inches and a lower one of 10 inches. Three clay twyeres were luted into the base and served to communicate the blast from three pairs of bellows. Owing to the presence of cowdung, the quantity of charcoal fuel required was small, only 50 to 75% to the weight of fused metal. Each furnace turned out 3-4.5 maunds of lead daily. The ores yielded 31-58% (average 40%) lead.

There are records that towards the end of the eighteenth century, the Marathas farmed the Ajmer mines. In 1818, the first British superintendant took over. At that time, 10,000 *maunds* of lead were being produced per year and sold at Rs 11 per *maund*. In 1846, the cost of production went above the market price of the product (Rs 16 per *maund*), and thus Ajmer lead could not compete with English lead. The Ajmer magazine ceased to take the metal and the mines were closed. 'The final closing of the Ajmer mines was due to the Mutiny (1857), and an anxiety on the part of the authorities to make lead for bullets scarce.' That was the inglorious end of the pre-modern lead technology in India.

Summing Up

The bulk of categorized information stated above has been obtained from the accounts of travellers and European geologists. The latter discovered novel features of physical geology in India, invented some specific terms like 'laterite' and observed new minerals like seypoorite or jaipurite, which was actually a ferro-cobaltite.

Through the centuries, several unit operations were practised—for example, evaporation of aqueous solutions, fractional crystallization, pre-modern crude techniques of mining, crushing, grinding, rudimentary steps of gravity separation, carbo-thermic reduction smelting, using charcoal as the reductant, amalgamation technique for purification of noble metals, etc.

The status of the mining techniques was not only pre-modern but also stagnant. There was hardly any improvement across the centuries. The Indian society was bereft of any tradition for mechanization; the mines had to be abandoned as soon as the water level was reached, since no mechanical pump had been invented. There were a few waterfall-driven crushing machines in the Kumaon hills and Chinese type blowing machines to boost smelter devices in Assam during the nineteenth century, but these were rare exceptions.

Commenting on the lead mines of Ajmer, Captain C.G. Dixon wrote in 1831:

> The system of restricting the communication to the tortuous course of the vein, precludes the practicability of removing the water; in as much as shafts, galleries, adits, and the usual concomitants found in similar cases in Europe, if not quite unknown, are altogether neglected... While we wonder at the simplicity, the leading characteristic of their operations, we are compelled to acknowledge our surprise, that the results are so favourable.[44]

The reputed historian Tapan Raychaudhuri could not defend the lacklustre achievement of Mughal India 'which had little curiosity about the laws of nature'; 'neither the elite nor the mass of producers manifested any curiosity, utilitarian or otherwise about things mechanical'[22] (p. 307).

> The marvels of Mughal architecture were achieved without the aid of wheelbarrows... Ovington ascribed the non-adoption of printing in India to a concern for the scribes' prospects of employment. The Dutch technique of quadrupling the rate of production of iron nails and cannon balls was banned for it might deprive many blacksmiths of their livelihood[46] (pp. 18-20).

Apart from the oppressive nature of the control of the mines and lack of administrative support, the industrial workers faced insulation from the intellectual world. Whatever scientific curiosity was nurtured by the authors of the *Rasaśāstra* texts did not permeate down to the level of miners on account of lack of educational and printing facilities.

Dharampal suggested that 'the link between the practitioners of various professions and the professors had largely snapped in India by the end of the 18th century', and that 'in a changed political climate such links would have been re-established'[47] (p. 43). We consider this to be somewhat wishful thinking. The aforementioned 'links' had rarely existed. The scholars hardly interacted with the workers, whereas the latter jealously guarded the secrets of their trades. This explains the severe paucity of indigenous literature on the subject. Most of our information has been derived from the writings of foreign travellers who closely examined the scenario.

There was a certain element of inevitability of the western people intruding into the Indian sub-continent, first through trade and then through modern technology, initially as traders and then as exploiters. The redeeming feature in our subcontinent was the gallant and persistent craftmanship of workers in the area of gems and non-gem minerals—in terms of both mining and processing.

V. IRON AND STEEL IN MEDIEVAL INDIA

The historical records pertaining to iron and steel in medieval India are scanty. Raychaudhuri and Irfan Habib[22] have provided some information in this regard. The mining areas lay scattered in the hilly regions beginning with Gwalior and extending to the tip of southern India. The Geniza records of eleventh and twelfth centuries[48] show that the Deccan exported iron and steel to the Middle East. Fakhr-i-Mudabbir considered Indian swords to be the best, and wrote that the Damascened sword (*maujdaryā*) was the rarest and fetched the highest price. Another kind was made of soft iron alloyed with copper and silver, and still another, from Kurij in Cutch, was made of steel.[49] *Rasaratnasamuccaya* of the thirteenth century AD described different varieties of iron and steel, which shall be presented later.

Manucci reported that iron ore from Gwalior mines was smelted and the metal was finally processed in different Mughal provinces like Bengal, Allahabad, Agra, Berar, Gujarat, Delhi, Indalvai, Indur and Kashmir. India exported over 10,000 pounds of steel in 1657 and over 5 lakh pounds of ironware in 1667. In the seventeenth century, the Dutch establishment shipped from India 20,000 ingots of 'wootz' steel.

During the 1660s the Dutch were active in developing the iron industry in the Godavari delta. They were in such an urgent need of pig iron, iron bands, iron bars and cannon balls, that they organized a manufactory system of production for these items in their factories. Varied iron products like nails, cannon balls, iron bars and iron bands used to be exported from Coromandel to Batavia. Spikes, bolts and anchors were produced in India for shipyards at Narasapur, Masulipatam, Pulicat, etc. In the Qutbshahi kingdom, Indalvai (near modern Nizamabad) was the centre for the manufacture of swords, daggers and lances, which were made from iron that was mined in the Kalaghat hills.[50-52]

Mining was widespread in Golconda, Karnataka and Mysore. Whereas Mysore iron and steel were of average quality and were used mainly for ploughshares, horseshoes, nails, etc. for local consumption, Golconda steel was famous all over India and even outside the sub-continent.[51,53] Another important area of iron ore mining and ferrous metallurgy in medieval India was Assam. The craftsmen supervising smelting were known as *ojhās*. Double-bellowed furnaces in Jaintia and other parts of the Khasi hills were more efficient than those in other parts of Assam. Mughal India used to import iron hoes and bell-metal vessels from the Ahom state.[54]

Ever since Babar invaded India in AD 1526 artillery and gun founding started in the sub-continent. Most of the earlier cannons were made of cast bronze and brass. Some of these, like the *Malik-i-Maidan* used in AD 1564, were excessively heavy and difficult to transport. The Bijapur kings requisitioned the services of many technicians from Turkey.[55] Gradually attention shifted towards fabrication of iron cannons.

Amir Fathaullah, a reputed mechanical inventor, had come from Shiraz in Persia to assist Adil Shah of Bijapur. During AD 1584-90 he served Akbar's foundry establishment with great distinction. New types of portable iron guns and matchlocks and *banduks* were made. A mechanically driven wheel was invented by the motion of which 16 gun-barrels could be cleaned in a very short time.[56]

Despite the presence of Turkish and European gun-casters in India, cast iron cannons were never introduced. During Akbar's regime the gun-barrel was made up of discs of wrought iron through which holes had been punched using hammers and chisels. These perforated discs were joined together by forge-welding, and the joints were reinforced by slipping red-hot iron rings over them, so that on cooling these rings contracted tightly onto the joints. 'The expertise in forging techniques was therefore diluting the need for casting technology.'[56,57] It is strange that despite the knowledge of refractory clay and the presence of foreign technicians, there was so much sluggishness in medieval India to pass on from bronze casting to casting technology of molten iron (higher melting point of 1535°C).

The Eighteenth-Nineteenth Century Scenario

Now let us proceed to record and critically review the writings of European travellers on the iron and steel scenario in eighteenth-nineteenth century India. This information can only partially compensate for the miserable lacunae in the medieval literature on the subject. One is immediately impressed with the diversities in ores processed, smelting techniques, furnaces, and products obtained in different geographical sectors of pre-modern India.

Valentine Ball recorded the diversity of iron ores mined, purified and processed by the Indian iron smelters[58] mentioning the reports of earlier workers.[59-65] We have briefly reviewed the literature regarding the mineralogical characteristics of different ore-bodies indigenously processed. Table 3 contains a summary.

In India, three types of furnaces were used: bowl-shaped open hearths, small blast furnaces and tall blast furnaces.[66-69] The Chota Nagpur small blast furnace was typically 4 ft 6 in. high, the blast being introduced by a single twyer. The Malabar district stückofen type tall blast furnace was typically 10 ft high. Several furnaces were built together over a common platform. Charcoal was the only fuel used and flux was rarely used. The Kathiawar furnace was exceptional, insofar as it resembled the European reverberatory furnace and was probably a technological import/adaptation. The flame produced by the blast over the burning charcoal played over the ore, which was kept in a separate compartment, instead of being mixed with the fuel. Thus reduction of iron oxide here was by carbon monoxide rather than by carbon.

India produced three kinds of product : crude wrought iron, pure wrought iron and wootz steel.

In places of large scale production such as Mysore or Birbhum, the refining forges were separate and the refiners bought the iron blooms from the smelters. Steel was made either by carburizing wrought iron in crucibles (wootz) or by de-carburizing cast iron.

Table 3: *Indigenous Processing of Iron Ores in Pre-Modern India*

Location	*Type of Ore*	*Comments*	*References*
Assam (Upper)	Clay iron-stone	3000 smelters in 16th/17th century	Hannay in *JASB, 25*, 330
Khasi & Jaintia Hills	Titaniferrous magnetic oxide	Beneficiation by raking	Yule[63,65]
Birbhum, West Bengal	Partly earthy, partly magnetic	Early production of *molten* iron: early 18th century	Hamilton[59]
Balasore, Orissa	Lateritic ore	Some collaboration with the Dutch in 17th century	Hamilton[59]
Palamau, Bihar	Three types of ore, Agarias preferring the magnetic type	Details on smelting by the Agarias	*Mem. GSI,* vol. XV, part 1, p. 112; Ball,[14] pp. 376-81
Sambalpur	Magnetite in metamorphic rock	Use of *Śālwood* charcoal	*Rec. GSI,* vol. X, p. 182
Tendukhera, Madhya Pradesh	High grade, slightly calcareous	Production of *kāchā* iron and *pākka* steel	Franklin[64]; Ball,[14] p. 386; Dharampal,[47] pp. 269-94
Gwalior	Rich deposits, now deserted	Very ancient tradition	Hacket, *Rec. GSI,* vol. III, p. 42; Ball,[14] p. 394.
Nimar & Malwa, Indore Territory	Barwai deposit is chiefly brown hematite	Mentioned in *Ain-i-Akbari*	Ball,[14] p. 397
Kathiawar & Cutch	Laterite of sub-nummulitic group	Reverberatory furnace for production of wootz (1838-40)	Ball,[14] pp. 400-02
Hyderabad	Two kinds of ore: lateritic and magnetic sand	Steel mines of Nirmal mentioned in *Ain-i-Akbari*	Voysey[62]
Cuddapah & Kurnool	Siliceous hematite and also lateritic	Series of iron-smelting villages	Heyne,[60] 1795 report
Mysore	Black sand iron ore in Venkatagiri	Manufacture of steel	Buchanan[61]
Chitaldrug in Salem	Non-magnetic ochrous limonite	Manufacture of wootz	Heyne[60]
Malabar or Kerala	Black magnetic sand	Rock 'laterite': term first coined.	Buchanan[61]

Recently, some studies were made[70-74] on the pre-modern technology by reconstructing ancient furnaces with the aid of the aged rural artisans, and measuring their operating conditions and analysing the raw materials and products. These replication experiments and data have helped quantify the pre-modern technologies. Let us now proceed to describe specific regional patterns in iron/steel technology specifically in southern, central, eastern and western India.

Pre-Modern Iron Technology in Southern India

During his famous journey through Mysore, Karnataka and Malabar (Kerala), Buchanan noted several places where lateritic (term coined by Buchanan himself: lateritis = brick) iron ores were processed and smelted.[61] At Colangodu in Malabar, four furnaces smelted black magnetic sand. At Velater there were 34 furnaces which belonged to a Mopla.

The lateritic ore was beneficiated by washing in a trough, open at both ends, which was placed in a running stream. The washed ore was largely magnetic. Buchanan provided admirably drawn sketches—sections and elevations of twin-shaft (250 kg iron per day) furnace which, according to Prakash 'conform to the design parameters of the modern 1000 TPD furnaces'.[67,70] We do not know whether the local artisans had been assisted during the earlier centuries by some Portuguese or Dutch travellers. These 10 ft tall furnaces were provided with pairs of bellows, peep-holes, hearth and slag pit. Dirar and others have recently attempted[72-73] to revive the ancient process in Kerala.

Charcoal Crisis and Atrophy of Indigenous Industry

Various reasons have been ascribed to the atrophy and extinction of the indigenous iron industry in India. Neither the Mughal government nor the people were aware of the new technological developments in the field of mass production of iron and steel, which were spreading fast in Europe.[69] The nineteenth century European observers consistently remarked about the lack of innovation in the Indian industries, the persistence of charcoal furnaces, the non-use of flux and mineral fuels, etc. On the other hand, some scholars believe that the most important factor was the British competition, intrusion into the Indian market, and ruthless elimination of the Indian industries. Dharampal writes: 'The disappearance seems to have resulted mainly from large-scale economic breakdown and hostile state policy.'[47]

The phenomenon was indeed complex. One technical factor was the charcoal crisis which Bhattacharyya has deliberated upon in his masterly paper.[68]

Enormous quantities of charcoal were needed in the indigenous processes. The proportion of charcoal to that of iron yielded was often 5:1. Considering the refining stage, all told about 14.5 tons of charcoal was used to produce one ton of refined wrought iron. According to an estimate, to produce 2500 tons of refined wrought iron, 140,000 tons of wood were required which could be obtained from 437 square miles of heavily wooded land! Production of charcoal from green wood was very wasteful. Bhattacharyya rightly commented that 'the rapid depletion of fuel source seems to have been one of the causes of the atrophy of the iron-smelting industry in the nineteenth century.'[68]

Europe had faced a similar problem in the sixteenth century, when forests began to be depleted on account of the charcoal-based process in the iron industry. An acute shortage of timber threatened the ship-building industry in England. The legislative restrictions on waste of timber and high price of fuel charcoal led to technical experiments with coal as a substitute for charcoal. Abraham Darby introduced coke for smelting iron in 1709. The use of coke spread rapidly in England, but it is noteworthy that as late as 1806, 11 out of 173 pig iron furnaces were still using charcoal.

One reason why coal or coke could not readily replace charcoal as fuel was that the conventional bellows were not sufficient to bring the mineral fuel to the required temperature. The coke furnace needed an engine two and a half times more powerful than that needed for a charcoal furnace for iron smelting. Charcoal could not be replaced with mineral fuel without auxiliary innovations such as superior blasting machines in place of the low-powered bellows.

At this stage, we may record a brief note on the use of coal and coke in ancient China. The Chinese had been using efficient double-acting bellows since the fourth century BC, the hydraulic bellows from the first century AD, and good refractory clay and surface coal from *c.* AD 400. Thus, efficient use of coke or coal demanded powerful and mechanized bellows which India did not have, except on the Chinese border of eastern India. China could develop furnaces having higher temperatures which melted iron, but they were aided by their possession of high-phosphorus iron ore, which substantially reduced the melting point of iron and enabled production of cast iron.[61]

Thus, the Indian persistence of charcoal furnaces, the non-use of mineral fuels, the non-use of flux, the non-availability of mechanized bellows, and the non-development of high-grade refractories represented different aspects of a complex phenomenon resulting in stagnation and atrophy of the indigenous craft. When the western visitors attributed the atrophy to the Indian artisan's indolence, indifference and resistance to technological change, they were perhaps a bit too harsh and uncharitable. There were several examples where the British entrepreneurs tried coal or coke in indigenous furnaces and failed on account of the technical reasons cited above.

On the question of improving iron manufacture in India during the nineteenth century, there emerged two schools of thought. One view, supported by Bhattacharyya,[68] and now endorsed by the present author, was that new technology employing coke, good refractories, flux, mechanization, etc. had to be introduced *all at once* instead of making piece-meal improvements in the indigenous method of production. The other view propounded by M. Fryar, *et al* was that the better method was 'to gradually engraft improvements on the native methods of manufacture.'[68] Dharampal felt that indigenous technology was hurt by 'unthinking transplanting of European sciences' and that the disappearance of the indigenous iron industry in India was on account of unequal British competition, 'large-scale economic breakdown and hostile state policy'.[47] Dharampal hardly attended to the technical considerations of the charcoal issue (as Bhattacharyya did). His observations had political overtones and would be discussed at the end of this paper.

Iron-Carbon Alloys in India

The thirteenth century AD text *Rasa Ratna Samuccaya (RRS)* contains a section (5.69-5.96) on the different varieties of iron. The descriptions clearly indicate that Indians were familiar with iron-carbon alloys and their different phases.

Kānta loha is a soft wrought iron with five sub-varieties of different magnetic properties.

The name *Munda loha* (second major variety) probably originated from *Mundia*, one of the metalsmith tribes in district Bastar whose ancient iron-making process was scientifically observed and recorded by Prakash and Igaki.[75] *Munda loha* had three sub-varieties: (a) *Mṛdu*, or soft was *drutadrāva* 'melting or softening quickly' and could be low m.p. grey cast iron; (b) *Kuntha*, expanding with great difficulty on hammering, could be mottled grey iron; and (c) *Kadāra*, which 'breaks on hammering' and could be white cast iron. The indigenous metalsmiths produced the last two brittle varieties unintentionally, when the temperature of the furnace rose high and the amount of charcoal used was large, resulting in high-carbon iron. They preferred the first variety, *Mṛdu*, which had a smooth surface, did not contain fissures, and was adjudged to be 'the best of the three'.

Tīkshna loha or carbon steel had six sub-varieties. These appreciably hard materials were carburized iron which could be hypo-eutectoid (less than 0.83% carbon) or hyper-eutectoid (over 0.83% carbon) steel. *Pogaras* mentioned in the text (*RRS*, 5.77-83) meant hair-like lines which might be surmised as white cementite streaks, coarse enough to be seen by the naked eye.

The *khara* sub-variety of *tīkshna loha* was free from *pogaras* (or had *pogaras* too fine to be seen), broke on bending and had 'mercury-like shining fracture surface'. The *sāra* sub-variety looked fibrous. The other four varieties were probably the products of hot forging and quenching. *Hṛnnāla* looked whitish black and contained *pogaras*; this was '*chhedane atiparusam*', very hard to pierce. *Vājira* looked bluish black and was 'full of hard *pogaras* and overspread by dense thin linings'. *Tārāvatta* developed good cutting edge. *Kālāyasa* was described as 'bluish black in colour, dense, smooth, heavy and bright in appearance, whose sharpened edges do not get spoiled even by hammering'. This description is close enough to that of the damascened steel swords 'of a dull blue colour marked with ten millions of meandering lines' which were compressed and elongated cementite grains or streaks in pearlite-graphite-martensite matrix.

Wootz—the Crucible Steel of India

The Indian crucible process for making high quality steel might have started before the Christian era, as evidenced by the excavations of crucibles dated 250 BC in Tamilnadu. Even earlier, quality Indian steel was presented by king Porus to Alexander (323 BC) and Kautilya's *Arthaśastra* referred (2.17.14; 4.1.35) to *vṛtta* or steel. The word *vṛtta* meant circle or disc, and could denote crucible-molten steel, *ukku* in Telugu or Kannada, *wuz* in Gujarati or *wootz*, which was the term spread all over the world by the traders from the Middle East.

In his excellent review,[76] Bennet Bronson grudgingly concedes that 'India may have invented or perfected from the second century AD the idea of crucible steel making, but that should not be accepted as given in medieval studies.' Bronson felt that 'wootz' was merely carburized iron showing brittleness; there were several processes for making it, some practised outside India; the art of converting wootz to steel objects like Damascus sword was known and probably perfected outside India.

Prakash contested[76b] Bronson, and indeed recorded circumstantial evidence, like the texts of *Bṛhatsamhita* of Varahamihira and *Rasaratnasamuccaya* (quoted by us earlier), etc. to prove that India was indeed the pioneer in producing different kinds of *wootz* and the end products of malleable steel. We also feel that *Rasaratnasamuccaya's* 'bluish black' *kālāyasa* (5.82), which had been mentioned much earlier in Kautilya's *Arthaśastra* (2.17.14), corresponded beautifully with the Damascus sword, 'the sharpened edges of which do not get spoiled by hammering', and thus establishes India's primacy not only in wootz but also in finished steel. We have discussed our views on iron and steel in ancient India elsewhere.[1]

The earliest western report on pre-modern Indian iron and steel was recorded by Havart.[77] Some of the earliest writings[59-65] by British travellers have been already quoted. A few researchers[78-83] specifically investigated wootz and Indian steel—both the processes and the products. Stodart, for example, sustained his interest in wootz right from 1795 to 1820, collaborating with Michael Faraday. These two collaborators tried to prove that 'wootz was in reality an alloy of iron with aluminium or various other metals'.[82]

It appears that there were *two* distinct processes for making wootz. The south Indian processes (there were minor variations), practised at Mysore and its surroundings, Tamilnadu and Sri Lanka, corresponded to carburization of wrought iron in crucibles. On the other hand, the Hyderabad process probably involved co-fusion in crucibles of wrought iron and white cast iron.

From Stagnation to Extinction

In many ways, the iron and steel industry of India was leading in the ancient, medieval and even pre-modern world. The outstanding achievements were made in the areas of carburization of wrought iron and *wootz* steel making. Why then did the indigenous industry stagnate and ultimately get extinguished?

There were two sets of factors which would explain the decline: (a) technical and (b) socio-political and intellectual. The second set was deeper in origin and more profound in results, affecting not only ferrous but also many other indigenous industries—in short, science and technology in India as a whole.

The first set, namely, technical factors, were related mainly to the charcoal issue which we have already deliberated upon. We have emphasized that new technology had to be introduced *all at once*. Replacement of charcoal by coke was not the only issue. Even the British entrepreneurs failed when they tried to introduce improvements in a piece-meal manner. Thus, their criticism against the artisans' 'resistance towards technological improvements' was rather uncharitable.[68]

The second set of factors may be listed in the following chronological manner:

1. The Hindu-Muslim rivalry prevented free diffusion of technical knowledge into and from India.
2. Neither the Mughal government nor the people were awake to the new technological developments in the area of mass production of iron and steel, which were spreading fast in Europe. Both were very slow in innovation and mechanization.
3. In Britain, the demand for cast iron cannons led to the sudden increase in size and productivity of blast furnaces, from 30 tons to 300 tons during the fifteenth century. And when the industry was rapidly burning up forests for fuel, the king intervened.[84] No such development took place in India due to a closed economy and lack of maritime adventure.
4. During the Mughal period, guns were made mostly of bronze and brass. Cast iron cannon was never an article of urgent need.[57] The barrels of Akbar's guns were made of discs joined together by forge-welding. The expertise in forging techniques therefore diluted the need for casting technology.[57,85]
5. Since the middle of the seventeenth century, the Marathas were purchasing cannons from the Europeans, but the casting technology for iron was never learnt. By the close of the seventeenth century, the European experts grew reticent about disclosing technological information due to the fear of social ostracization as well as legal action, which was becoming increasingly evident in the west.[86] Later, this desire to isolate technology from the Indians became a part of the official colonial policy.
6. The Britishers, who initially arrived as traders, started flooding the Indian market with cheap iron produced in Britain on a large scale. This coupled with the rising cost of production by the indigenous methods forced the artisans to quit their jobs for survival.
7. The Britishers were very selective in extending financial assistance to entrepreneurs interested in reviving the Indian iron and steel industry. The proposal of Mr Inder Narain Sharma for large-scale production of iron in Birbhum in 1774 was turned down, whereas a few British entrepreneurs were granted the necessary permissions.[87]
8. During the latter part of the eighteenth century, the number of iron and steel furnaces in India was in the region of 10,000, producing on an average 20 tons per year per furnace. From about AD 1800 onwards, India was treated as a consumer of British manufactures, and Dharampal has rightly commented that the disappearance of the indigenous industries resulted from 'large-scale economic breakdown and hostile state policy'.[47]
9. However, Dharmapal overshot his point when he asserted that the sciences and technologies of India 'had reached a desirable balance before the eighteenth century' and 'were usefully performing the tasks desired by Indian society'.[47] We wish we could accept his assertion.

Dharampal referred to the 'link' between the practitioners of various techniques and 'the professors of the theoretical knowledge'. The link, 'largely snapped in India by the end of the eighteenth century', could have been re-established, according to Dharampal, 'in a changed political climate'. These are indeed brave patriotic words!

We are not aware of any Indian 'professor of theoretical knowledge' in the pre-modern era who could explain the extractive and physical metallurgy of iron and steel. As a matter of fact, the theoretical knowledge pertaining to chemistry and metallurgy was barely evolving at that time even in the west, and the Japanese could easily see that this new knowledge had to be borrowed from the west.

When Dharampal opines that 'unthinking transplanting of European sciences and technologies in India resulted in retarding and blunting of indigenous innovation and creativity'[47] the topic certainly demands detailed discussion and debate. Of course, there is merit in a systematic study of the ancient technologies. The pre-modern iron and steel industry of India held certain promises which could be considered for exploitation in the modern context. Rice-husk reinforced refractory crucibles could still be tried for high temperature work. The ancient art of making wootz steel and Damascus blade could be simulated to make ultra-high carbon steel having strength as well as ductility.[88] Some scholars believe that the pre-modern techniques of direct smelting of iron ore in small bloomeries and of crucible production of special steels might be revived with certain modifications.[72]

VI. METALS AND ALLOYS IN MEDIEVAL INDIA

India's Pride in Zinc and Brass Metallurgy

We have fully documented elsewhere the primacy of India in ancient brass and zinc metallurgy, and the technical details of the glorious tradition which flourished during the medieval period continuing beyond the middle of the eighteenth century.[2]

There was large-scale manufacture and widespread use of zinc and brass in medieval India. Brass icons of India during the period AD 1350-1752 had high zinc content, sometimes in the range 35-40%. One item assaying 36% Zn was dated AD 1752—five years before the war of Plassey, and eight years before the Zawar production slowed down on account of the Maratha invasions. During the medieval period, the Moghuls had used brass (as well as bronze) for manufacturing guns, and artisans of Bidar (83 km from Hyderabad) used high zinc (84%) brass or *bidri* alloy for ornamentation over it by gold or silver wire. *Ain-i-Akbari* reported brass containing 28%, 33% and 42% zinc (hard and brittle to be cast).

The etymology of the words denoting zinc became clearer. *Madanapāla-Nirghaṇṭu* of AD 1374 mentioned *Yaśadam vaṅgasadṛsam* or the 'zinc metal (*yaśada*) like tin'. *Yaśada* means that which gives *yaśa* or fame; the connection was clear in so far as zinc was known to produce the famous gold-like yellow alloy of brass (vide second century AD text *Rasaratnakara*, 1.3). The European word 'zinc' was probably derived from yaśada; the Sanskrit word became *jast* (Abul Fazl) and *dastā* in several Indian languages.

In 1597, Libavius (AD 1545-1616) received Indian zinc, which he called 'Indian or Malabar lead'. As late as 1751, Postlewayt's *Universal Dictionary of Trade and Commerce* had to admit ignorance of how the zinc was made in the east.

It has been established that there was a technology transfer from Zawar in India to Bristol in England sometime before 1730. The evidence contradicts the usual notion that the vector of science and technology transfer had always been from the west to the east. Indian traditions have frequently benefited the growth of the Greek, Arab and medieval European sciences. On brass and zinc metallurgy, the primacy of India in the ancient and medieval world is now beyond any dispute.

Bidri and Other Artworks in Pre-Modern India

In pre-modern India several traditions of artworks based on metals, alloys, gems and stones flourished and became internationally famous. Many of these traditions started in ancient India and continue vigorously in modern India.

Bidriware, the sleek and smooth dark coloured metalwork with intricate eye-catching designs on its glossy surface, is famous all over the world. This metalwork as well as the technique to produce it are found in India alone.[89-93]

Bidri is an alloy which contains 76-98% (normally around 95%) zinc, 2-10% copper, up to 8% lead, 1-5% tin and traces of iron (vide Table 4). Occasionally, high percentages (19.9) of lead and tin (11.4) have been noted. However, mostly it is a high-zinc-low-copper alloy. Up to 1% copper in zinc forms the terminal solid solution; at above 1% copper the ε phase precipitates at the grain boundaries in this phase field. The usual yellow brass may contain not more than 40-50% zinc, often less; copper constitutes the remainder or the predominant phase. Thus brass and bidri represent the two opposite ends of the zinc-copper phase diagram.

The bidriware's surface is first made smooth and a solution of copper sulphate applied to it to darken it temporarily for engraving. The engraving tools cut the intricate but delicate tapestry of design into the metal, which is then lighter in colour than the darkened surface and enables the pattern to be seen clearly.

Table 4: *Results of Atomic Absorption Spectrometry Analysis of Bidriware* (taken from La Niece *et al*[92]).

Victoria & Albert Museum acquisition no.	*Description*	*% by weight content*				
		Zinc	*Copper*	*Lead*	*Tin*	*Iron*
2539-1883 I.S.	Huqqa	91.2	3.2	2.9	1.2	0.2
1578-1904	Huqqa	98.0	3.3	1.4	0.1	0.2
45-1905	Huqqa	88.2	3.0	2.9	0.7	0.5
I.S. 46-1977	Weight	92.6	4.7	1.4	5.7	0.1
1479-1904	Ewer	89.3	4.8	0.8	<0.1	0.8
I.S. 10-1973	Bowl	92.1	3.6	1.4	0.3	0.1
02942 (I.S.)	Huqqa	84.6	3.3	1.0	0.1	0.5
I.S. 131-1958	Pan box	95.0	3.1	1.5	0.1	0.1
I.S. 181-1965	Huqqa	76.1	10.1	8.2	11.4	0.6
I.S. 31-1976	Bottle	98.6	2.6	1.0	0.4	1.2
857-1874	Huqqa	92.1	3.6	0.8	0.6	0.4
I.S. 17-1970	Pan box	81.3	2.0	2.0	<0.1	0.5
02949	Bottle	83.8	2.5	6.6	<0.1	0.2
02949	Bottle	93.2	2.4	1.1	0.1	0.2
855-1874	Huqqa	99.2	2.6	0.4	0.2	0.6
02941 (I.S.)	Basin	91.2	2.8	2.1	0.1	0.2
I.S. 4-1977	Huqqa	83.6	3.7	0.8	<0.1	0.6
I.S. 19-1978	Huqqa	85.3	4.6	3.0	1.3	<0.1
120-1886	Bottle	86.7	5.3	1.9	0.2	0.1
I.M. 224-1921	Bottle	91.7	3.6	0.7	0.7	0.7
2066-1883	Box	79.6	2.7	19.9	0.1	0.5
1402-1903	Huqqa	95.3	2.7	1.1	3.0	0.5
I.S. 11-1973	Vessel	97.6	3.4	1.8	<0.1	0.1
I.S. 39-1976	Huqqa	89.2	3.4	0.5	0.7	0.7
I.S. 19-1980	Huqqa	80.6	3.6	7.3	6.4	0.9
856-1874	Huqqa	77.4	4.4	0.9	0.4	0.1

The piece is then handed over to the inlayer. The inlay may be of silver, brass or occasionally gold. The final stage after the inlay has been burnished, is to blacken the surface of the piece so that the inlay stands out. This is done by applying a paste of ammonium chloride, potassium nitrate, sodium chloride, copper sulphate and mud which darkens the body by producing a characteristic black patina while having no effect on the inlay. The paste is later washed off and finally oil is rubbed into the piece to deepen the blackness of the patina. The result is a lustrous dense black body contrasting with the brilliant lining—white (silver) or yellow (brass or gold).

Replication Experiments and Chemical Hypothesis

La Niece and Martin[92] performed some replication experiments to show that the black colour of the patina was due to copper. The recipe for blackening the bidri metal has the main constituents in a warm solution of potassium nitrate (one part), often substituted by well-urinated soil, and ammonium chloride (four parts).

In a replication experiment a clean pure zinc sheet was immersed in the above solution, when a pale grey patina of zinc oxide and chloride was produced. When the experiment was repeated with the addition of copper sulphate, a reasonably good but *superficial black* patina formed almost instantaneously. Again, only zinc oxide and chloride were the main crystalline products. XRD analysis identified $Zn_5(OH)_8Cl_2, H_2O$, ZnO, Zn and Cu_2O (cuprite) as the crystalline phases. None of these explained the blackness of the patina which was amorphous and contained copper.

Similar experiments were performed with a specially prepared alloy of zinc containing 3% copper. When this alloy was dipped in a warm solution of potassium nitrate and ammonium chloride, it turned to deep black instantly and the patina was even and *adhered well* to the metal surface. This was found to be non-crystalline. Scanning electron microscopy showed the patina to be about 10μm thick assaying 30% copper as a contrast to 3% in the bulk. Zinc and chlorine were the other elements detected.

La Niece and Martin have postulated[92] that ammonium chloride preferentially dissolves the zinc from bidri and the resulting copper-enriched surface or the copper-rich ε phase precipitate gets oxidized by potassium nitrate, producing the black colour. The use of clay does not seem to be crucially important. It could merely serve as a source of alkali nitrate and as a poultice to absorb the unwanted zinc chloride formed during the process. The matt black patina is easily damaged by the standard cleaning techniques used to remove the white decomposition products from the zinc.[90]

History of the Art Tradition

The mystery of the black patina is not yet fully solved. The inventors of the tradition did not have any idea about the underlying scientific principles; they merely hit upon the arts and crafts aspect of the process.

The craft of bidriware is a kind of damascene work which has been defined by Sir George Birdwood as 'the art of encrusting one metal on another, not in *crustae*, which are soldered or wedged, but in the form of wire, which by under-cutting and hammering, is thoroughly incorporated into the metal which it is intended to ornament'. The original tradition at Damascus was to encrust gold wire, and sometimes silver wire, on the surface of iron, steel or bronze.

A group of damascene craftsmen moved from Syria or Iraq to India. Some of them were at Ajmer in Rajasthan and hit upon the idea that damascening could be done on the base of high-zinc-low-copper alloy. Zawar in Rajasthan was the major zinc-producing centre in the medieval world. The said craftsmen moved down south during the fifteenth century AD and settled at Bidar (17°55' N and 77° 32' E.) near Hyderabad. When the art flourished in that place for centuries, it became known as bidriware craft.

The earliest known craftsmen like Abdullah-bin-Khaiser and his pupil Sivanna worked at Bijapur. Historical evidences indicate that the beautiful articles presented to Alauddin Bahamani-II (AD 1434-57) on the occasion of his coronation impressed him very much, and he invited the craftsmen of Bijapur to settle at Bidar itself. The workers used to prepare beautiful huqqa bases, ewers, bowls, pan boxes, basins, bottle, slabchis, cot legs, etc. The varieties of workmanship of the design consisted of *tara kashi* (inlay of wire), *tahnishan* (inlay of sheet) *zaranishan* (low relief, inlay levels with surrounding area), *zarabuland* (high relief, for example, silver over a lead pad), *aftabi* (design in overlaid metal sheet), etc.

The Russian traveller Althanasins Nikitin, who visited Bidar during AD 1470-74, took with him some of the early bidriware specimens for presentation to the Russian emperor. A large number of articles of bidriware were made for presentation to the Prince of Wales when he visited India in 1875. These now adorn the collection of the Victoria and Albert Museum, which has published a comprehensive bibliography and illustrated catalogue on the subject.[92] Bidar and Hyderabad museums also have beautiful collections of this kind of ware.

Mahmud[93] has given some details about this craft under specific headings like raw materials, tools, implements, process of production, preparation of alloy, mould making, casting (such as a goblet), etc. The manufacture of bidriware was carried on under a system of division of labour. The moulder prepared the alloyed metal, cast the vessel and turned it to its proper shape on his lathe. The carver engraved the patterns on the surface of the vessel, and the inlayer designed the patterns, inlaid the ornament of gold, silver or brass, and finally polished the article. In pre-modern India, there were four notable seats of bidriware manufacture: Bidar, Lucknow, Purnea (Bihar) and Murshidabad (Bengal).

Tin-Coating of Metallic Utensils

Some time in the pre-Christian era, Yajnavalkya noted that tin and lead vessels could be cleaned by alkali and acid water, whereas vessels made of copper alloys like *kāmsya* (bronze) and brass should be cleaned by ash and water (*Ācārādhyāya*, 190). Thus, acid-resistance of tin was known in ancient India. Bodhāyana referred to solid tin vessels. It is not known whether tin-coating of metallic utensils used to be done in ancient India for protecting such utensils, particularly cooking vessels, against chemical action caused by sour or acid foods placed in them. During the medieval period, however, this became a well-known practice.

Gode has reviewed the literature[94] and opined that this tradition of tin-coating was started in India during the Muslim period. Along with Bahmani coins (AD 1347-1500), a copper container with both internal and external coatings of tin was discovered in the archaeological excavations at Brahmapuri. Sanskrit texts of the period 1676-1710 mention tin as *kalhai/kalāya* and tinning as *kalāya-lepa*. The word *kalhai* or *callai* was Arabic, and it might have been derived from Sanskrit *kastīra* or Greek *cassiteros*.

The Muslims were fond of tinning their cooking vessels not only the inside portion as Hindus did, but also the outside part. Abul Fazl reported that the copper utensils for Akbar's personal use were tinned twice a month whereas those of the princes and the harem only once a month. During the early part of the seventeenth century (AD 1600-50) the British East India Company sold a lot of tin to the Indians, the Arabs and the Persians. With the discovery of new tin ore reserves in Malaysia, the British trade dwindled. Major uses of tin in the Muslim world were in making bronze, bell-metal and tinning vessels of copper and copper alloys.

Tinning was popular in the Hindu medieval world as well. The saint-poet Surdas wrote: *Āi udharī prīti kalaī*, comparing love with tin-coating. *Śivatattvaratnākara* (c. AD 1710) wrote *'kalāya-lepita pātre'* (in a tin-coated vessel). *Rājadharmakośa* (c. AD 1676) recorded *'kathilam vaṅgamucyate ... kalhaikārah sīsakāro'*, etc. Kathila, kalāya, kastīra, vaṅga, raṅga, etc. were different names for tin. During Shivaji's time *kalhāikāra* or *kalhāigār* was probably *sīsakāra* also (i.e. the same people who practised the arts of both tin-coating and lead-coating).

The *Bombay Gazetteer* of 1904 contained notes on *kalaigar*, a caste of Muslim tin-smiths, in districts Ahmadnagar, Poona, Satara, Sholapur, Belgaum, Dharwar, Bijapur and Nasik. The present author recalls his childhood days of the late 1930s and early 1940s when *kalaiwalahs* were frequent visitors to the households in Calcutta. As Gode observed, they moved about from house to house, doing the work of tin-coating of copper and copper-alloy vessels on the spot using instruments and materials they carried with them. They had regular shops in the cities also. Their trade dwindled with the increasing use of aluminium and steel for making cooking vessels and other household items.

Some Alloys in Medieval India

We have already quoted *Ain-i-Akbari* reporting three types of brasses. The other alloys current in sixteenth-eighteenth century India were *kāṁsya* or *kānsā* or 4:1 copper-tin bronze (*safid-rui* in Persian), 8:3 copper-lead *bhangar* (*bad-rui* in Persian), etc.

Bronze was widely used for making Hindu icons, utensils and cannons. *Malik-i-Maidan*, the largest cannon of the medieval period (AD 1549) was cast out of an alloy containing 80.4% copper and 19.6% tin. The term *rui* was used to indicate a variety of materials like copper alloys containing Sn, Pb or even Sb.

Iqbal Ghani Khan has drawn our attention to some of the alloys used in medieval India, probably imported from central Asia, and the confusion regarding their nomenclatures.[57,95,96] As early as 180 BC the coins of the Bactrian ruler Euthydamus-II contained up to 20% nickel. During the same period, Taxila bangle and plate assayed 18.88% and 21.35% nickel, respectively. Tin and nickel ores were available to the artisans of Shash, Ferghana, etc.

Alloys having exotic names like *ahanchini, kharchini, taliqun, haft-josh*, etc. were mentioned by Jabir ibn Hayyan (AD 760) and even later by Al-Beruni, etc. These were mostly Chinese or central Asian alloys—copper alloyed with nickel, arsenic, antimony, etc. Most Muslim scholars including Abul Fazl were incoherent as regards the exact composition of these alloys.

I.G. Khan has identified *kharchini* or *kharsini* as the Chinese cupro-arsenic alloy which was used in making poisonous arrow-heads, mirrors (due to its white surface), gongs, and so on. La Niece *et al* have shown[97] that like the third century BC Libyan 'white copper' coins, the base of the twelfth century Mañjuśrī statuette in western Tibet contained high precentage of arsenic (7.4%) and even higher (14.0%) of the element coming to the surface on account of inverse segregation. The twelfth century text *Rasahṛdaya* (18.23-69) actually described the process of 'heating of copper with an equal weight of *tala* (orpiment As_2S_3) and *vaṅga* (tin) to convert this into silver'.

The term *kharchini* was later used to denote antimony-bearing alloys. Al-Beruni reported the export of lead-antimony and copper-antimony amulets, hair-tweezers and other small items to India from the present day Afghanistan region. Locally available Sb_2S_3 ore was easy to smelt giving low m.p. (630°C) antimony, which was excellent for small castings, since it expanded on cooling.

Haft-josh (Persian equivalent of the Indian *sapta-loha*) was a seven metal alloy consisting of gold, silver, copper, tin, iron, lead and zinc. The Hindu *asht-dhātu* or the eight-metal alloy contained the above seven and mercury (used as amalgam with gold). These multi-metal alloys were used for making amulets and icons and were believed in Persian and Indian worlds to possess magical and religious values.

Theory of Metals and Alloys

In *Ain-i-Akbari* Abul Fazl discussed[98] the 'origin of metals' which could be taken to represent the knowledge the Muslims had on the subject at the end of the sixteenth century. Following the Aristotelian tradition Abul Fazl viewed the entire material universe to consist of *four elements*—fire, air, water and earth—suitable mixtures of which produced *bukhār* (gas) and *dukhān* (vapour). Mixtures of *bukhār* and *dukhān* produced quicksilver, the mother, and sulphur, the father, of the seven metals (vide *haft-josh* discussed above).

Abul Fazl was very confused about metals and alloys, and the compositions of the latter, particularly *ahanchini, kharchini,* etc. He listed brass and bronze as metals rather than alloys. On the other hand, *Rasaratnasamuccaya* (10.72) clearly mentioned gold, silver, copper, tin and lead as the six *āyasa* or metals, and bronze and brass as *kṛtrīma* or alloys. Dhātukriyā or Dhātumañjarī (63) mentioned brass as an alloy *(upa-dhātu)* made of copper and zinc.

Abul Fazl's writings reflected the ignorance of the then Muslims about zinc, the metallurgy of which had been vividly descirbed by the *Rasaśāstra* texts many centuries ago:

> Jast (yaśada or zinc), which according to the opinions of some is Rūh-i-tūtiyā, and resembles lead, is nowhere mentioned in (Arabic and Persian) philosophical books, but there is a mine of it in Hindustan in the territory of Zawar.[98]

The above quotation also sadly reflects the communication gap between the Hindus and the Muslims of late sixteenth century India. There were some (but not enough or intimate) technology exchanges between medieval India and the Islamic world.[99] Right-angle gearing, spinning wheel, distillation, paper technology, Muslim architecture using lime- and gypsum-mortar, etc, were transmitted from the Islamic world to India. The knowledge of making iron stirrups, horseshoes and horse-armour were also imported from outside. Babur described eight furnaces simultaneously feeding one large cannon mould for bronze casting. Artisans employed by Akbar made portable cannons and iron barrels by lateral rolling of iron sheets. On the other hand, India exported the technologies of parallel worms, double rollers, bowing, cloth-printing, etc.[99] There was the technology transfer of zinc smelting by reduction-distillation practice from Zawar to England.[2] But these were mere exceptions to the rule that very little *basic scientific* knowledge was exchanged between medieval India and the outside world.

VII. CONCLUDING REMARKS

In this paper we have recorded some details about selected gem minerals, non-gem minerals, metals and alloys in medieval and pre-modern India (tenth-eighteenth century). Most traditions, like those relating to pearl, carnelian, beryl, diamond, copper, zinc, iron and steel, had originated in ancient India. In these fields India learnt very little from the outside world, although it did import traditions in saltpetre, gunpowder, jade, copper-based alloys containing nickel, arsenic and antimony, tinning of copper vessels, soap and paper, etc.

We have analysed the reasons for medieval decadence in India. The underlying factors lay in both the Hindu and Muslim cultural traditions. The Hindu society was fragmented with caste and bedevilled with vainglory and religious obscurantism. On the other hand the Muslim invaders brought little relief to the Indian intellectual world. The glorious traditions of Muslim science, which flourished in tenth-twelfth century Spain, benefiting the emerging European science, had little impact on the intellectual climates in Arabia, Persia or India. Irfan Habib has been very candid on this point:

> That time (after the death of Ibn Rushd or Averroes, AD 1198) science received a setback throughout the Islamic world. There was a heavy onslaught on reason and philosophy

> in which Ghazali (d.1111) played an important part. In medieval India, therefore, Islam was received when the scientific tradition in it was in the process of decay. Abul Fazl at the end of the 16th century was to mourn 'the blowing of the heavy wind of *taqlid* (tradition) and the dimming of the lamp of wisdom. Of old the door of 'how' and 'why' has been closed; and questioning and enquiry have been deemed fruitless and tantamount to paganism' (*Ain-i-Akbari*, vol. II, p.3).
>
> The Mughal Empire has produced not a single worthwhile text on crafts or agriculture, however, many volumes of poetry or histories it might have to its credit.
>
> The Indian rulers' refusal to respond to western science and thought was thus at par with their indifference to technology. Both added up to an enormous intellectual failure of the ruling class. That failure must always be assigned its due share of responsibility for what did not happen in India—a quickening of technological change even remotely reflecting, if not independently corresponding to, the accelerating progress of Europe.[100]

Why did the Indigenous Industries Collapse?

In Europe there was a gradual transition from the medieval to modern industries. In Japan, the transition was sharp but the earlier industries did not suffer catastrophic collapse as they did in India. The decline and demise of Indian traditions in mineral and metal industries were partly political, but there were other deeply ingrained reasons, too.

With regard to the diamond industries, we have mentioned that the gem-bearing reserves were gradually depleted. But there was never any total exhaustion of the rocks. There was not even rudimentary geological knowledge in the country and no scientific guidance was available to the miners. Then there was the severely oppressive nature of the rulers' administration, and in the case of diamond, the emergence of the more competitive mines of Brazil proved a decisive factor.

Mining of gem, non-gem and metalliferrous minerals was most unscientific. The problems related to water-logged mines, their drainage, lack of pumps, lack of mechanization, etc, which had earlier been faced and successfully tackled by the westerners, continued to haunt medieval and pre-modern India, gasping in vain for solutions.

In the case of the iron industry there were special problems related to destruction of forests, paucity of charcoal and the increasing cost of transportation of fuel to the smelting sites. Europe was gradually switching over from charcoal to coal and the new furnaces needed mechanized blowing of air. India had limited access to this technology (only in the eastern part adjoining China), but this was not adequate for the country.

Tapan Raychaudhuri presented a brief but critical and incisive analysis regarding the decadence of Indian industries during the pre-modern period.[101] He wrote:

> Both early modern Europe and medieval China were far ahead of mid-eighteenth century India in such crucial fields of technology as the use of wind and water power, metallurgy, printing, nautical instruments, and basic tools and precision instruments.... The pattern was not one of total stagnation, but rather of a general indifference to labour-saving devices.

It is not that medieval India was unaware of the scientific and technological developments taking place in the west and in China. The Indian rulers were aware of clocks, printing presses, nautical instruments, telescopes, various mechanical gadgets, wheelbarrows, simple pumps and so on. Yet their response in terms of indigenous adaptation of these was strangely apathetic.[86, 102-104] Why this apathy, is a question that merits a deeper analysis.

Common artisans improved their techniques of iron-making, ship-building, etc, whenever and wherever they came in contact with foreign experts, as in Surat, the Coromandel coast, etc. But the foreigners, particularly the Dutch, were usually secretive, and the rulers of the country never appreciated the forces that the emerging modern science and technology represented.

The intellectual isolation was manifold. Debiprasad Chattopadhyaya mentioned the evils of casteism which had ruined the glorious Hindu science in ancient India and continued to haunt medieval India. It haunts us even today.[7] The major impact of casteism was over-secretiveness in hereditary professions related to philosophical and practical knowledge.

This kind of internal intellectual isolationism haunted the Muslim world in India as well. Ever since the days of Mahmud Ghazni, the Muslim invaders were hopelessly isolated from their own scientific and intellectual thought-world, which had flourished in the countries of the Islamic tradition during the eighth-twelfth century AD. The Mughals did not cultivate the earlier maritime adventurous spirit of the Arabs and Persians.

Bernier wrote in his *Travel* on the oppressive nature of the administration during the later period of the Mughal regime:

> The country (Mughal Period) is ruined by the necessity of defraying the enormous charges required to maintain the splendour of a numerous court, and to pay a large army maintained for the purpose of keeping the people in subjection (majority Hindus)... A profound and universal ignorance is the natural consequence of such a state of society as I have endeavoured to describe. Is it possible to establish in Hindustan academies and colleges properly endowed?

The Hindu subjects, divided by caste, remained bitter against the steadily rising Muslim fundamentalism. Two parallel cultures co-existed under considerable strain. The intellectual isolation between the two communities seriously affected the flow of scientific knowledge within India. This could have been one of the reasons why scientific revolution did not take place in India;[104] Raychaudhuri has also accepted this point of view.[105]

Following Gandhi and Nehru, Dharampal[106] recorded his esteem and appreciation for the inherent strength of medieval science in India. He believed that the inherent weakness could have been overcome with time and political stability. Indian history tells us a different story: eight centuries of time gave us neither political stability nor good science!

Dharampal complained against 'unthinking transplanting of European sciences' in India; he felt that western science was thrust upon India and too quickly. But Sen[107] and Blanpied[108] have shown that the British introduced modern science into India too slowly and in a niggardly fashion.

The present author is unable to accept Dharampal's view. That western colonialism and capitalism were different from modern science and technology in character, has not been appreciated by Gandhians and Marxists. Raja Rammohun Roy wisely distinguished between the two faces of the west. During the eighteenth/nineteenth century the Japanese sportingly abandoned their Chinese moorings and learnt modern science from the western colonial powers. After all, modern science has evolved out of Indian, Arabic, Chinese and European contributions; then why should we have called it 'western' or alien science?

What we accept from Dharampal's thesis is the fact of brutal economic and political exploitation of the Indian people by the British, starting from the eighteenth century. Where we are in perfect unison of thought with Dharampal[47,106] is the legitimate pride in the indigenous industries and traditions in pre-modern India. Here the bulk of the credit goes to the indomitable artisans representing so many castes, religions, languages and sub-cultures. They exhibited gallant and persistent craftmanship. Their vitality was sustained through centuries, and could not be extinguished by Hindu obscurantism, or Muslim fundamentalism or British colonialism.

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CHAPTER XII

Indian Agriculture—A Historical Perspective

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I. INTRODUCTION

No periodization in history satisfies the requirements of all the cases. But, surely, the divisions proposed considering the events of political history cannot be expected to project faithfully the developments in the spheres of culture and civilization. The chronological limits, accepted here, have certain advantages. Discarding rigidity about a sharp dividing line, based on a precise year, it spans the developments spread over a millennium. The transition from the ancient to the medieval period, on the one hand, and that from the medieval to the modern, on the other, has been a gradual and slow process, which cannot be contained within precise dates. This has led to the suggestion of a number of dates according to the criteria selected by the concerned proposers. Admitting the possibility of dividing a period into a number of sub-phases, with certain pronounced features in terms of some important items, we find in it a few distinguishing characteristics of several aspects of society and culture. Incidentally, it may be pointed out that in the period under review India came into a closer contact with countries in west Asia and central Asia, which influenced Indian life and society.

The vast expanse of land involved demands an appreciation that agricultural technology had a wide range of variation. The techniques and tools differed from region to region and depended on their geographical peculiarities. The selection of crops and adoption of the relevant technology were conditioned by local requirements and resources. The level of progress in the material culture of the region was another important factor.

The Indian cultivator is proverbially conservative and the pace of change in the techniques of agriculture has been very slow. In the later Vedic age agricultural practices and techniques had taken some shape.[1] There were indications of improvements in techniques and implements and development in the knowledge relating to agriculture in subsequent periods, though it is not possible to determine precisely the chronological chart of these changes.[2] An analysis of the relevant evidence shows a systematized knowledge of agricultural techniques which did not differ radically from practices before the advent of modern technology and mechanical tools.

Sources of Information

For this period we have a rich fund of information. Besides casual references in the texts of the period, inscriptional and archaeological testimony is particularly useful for irrigational work.

The paucity of evidence bearing directly on the techniques of agriculture is an initial difficulty in the study of the subject. Much useful information, by way of casual references, is to be found in the administrative and revenue records, historical accounts, epistolary collections, topographical works and documents and travel accounts of Europeans. But these references are often vague and general statements, without any bearing on the technical details.[3]

The only Persian text dealing with agriculture in the period was the *Nuskha dear Fan-i-Falāḥat*,[4] which was a fragment of a large book, the *Ganj-i-Bādāward* of Amānullāh Khān Husainī,[5] son of Jahangir's noble Mahābat Khān. The text acknowledged its indebtedness to *Kitāb-i-Shajaratu-n-Nihāl*, to be identified with *Risāl-i-Falāḥat* written in Persia. In revising the earlier work, Amānullāh incorporated information about Indian fruits and crops.

The earliest available full Sanskrit text on agricultural practices was the *Kṛṣi-Parāśara*,[6] which was possibly composed towards the beginning of the eleventh century. It provided information on paddy cultivation. The next full text on agriculture was the *Kāśyapīya Kṛṣisūkti*.[7] We do not have any information about its author and provenance. It seems to have been composed some time in the medieval period.[8] Interestingly, it covered all the aspects of agriculture.

In the medieval period, manuals on agriculture were prepared in some provincial languages. They have not been subjected to any serious analysis, but are not expected to yield any significant new information.

The allied area of horticulture attracted systematic attention under court patronage. Under the name of Vṛkṣāyurveda, the discipline could be traced to a time before the fourth century BC. Surapāla composed his magnum opus entitled *Vṛkṣāyurveda* in the twelfth century.[9] Copies of the text were widely prepared at many centres. Subsequent writings, like the *Upavanavinoda*, a section of the *Śārṅgadharapaddhati*, drew heavily from this text. Some manuscripts, which purported to be new compositions were really copies of this text with some variations.

The interest of the ruling class, nobles and feudal chiefs resulted in the composition of several texts on arbori-horticulture, like *Puṣpavāṭikāvidhi*. *Vṛkṣadohadaprakāra*, and *Vṛkṣāropaṇaprakāravyākhyā*. But these were not of much merit, as they lacked in fresh knowledge or techniques. This was true of other similar texts prepared in provincial languages by rich men of taste and culture and preserved in family collections and manuscript libraries.

As in earlier times, some enlightened rulers got compiled or themselves prepared encyclopaedic works covering many areas of science and culture. These included sections on agriculture and horticulture. Being mostly in the form of compilations from earlier writings, these have not been studied with care.

One such text is the *Śivatattvaratnākara*, written by Kaladi Basava Raja in 1709.[10] The second section of its third chapter deals with meteorology, including clouds and constellations favourable to rainfall. Two sections in chapter VI relate to horticulture. The topics dealt with are classification of flora, trees to be planted, time for planting and watering, manures, decoctions for grafting, improving the yield, curing diseases and barrenness, and creating new varieties.

II. FACTORS OF CHANGE

As the evidence is not very vocal, it is difficult to give details of the state of agricultural technology and to identify the factors responsible for change. In this period contacts between India and central Asia were quite close.[11] The exchange of goods and people between the two regions, the reputation of central Asia as a centre of culture, and the personal and emotional regard of the medieval rulers and chiefs for central Asia, provided the necessary background for central Asian techniques, even in the field of agriculture, to be imported to India.

The first arrival of Europeans was towards the close of the fifteenth century. With the expansion in the sphere of European contacts and the growth of European political authority, doors were opened for European culture, science and technology to enter into Indian life and society. This paved the way for the arrival of South American fruits and crops. Western tools and techniques were not quite appropriate for India and hence could not receive acceptability in the beginning. The fruits of scientific study and methodology took a long time to be accepted, which was mostly after the period under study.

Roots of Subsistence Agriculture

In the period there was no significant factor providing incentive for improvements in the techniques of agriculture. The rulers did not make any effort to increase the tax-paying capacity of the peasants. They chose to adopt the politically expedient policy of leaving the peasants a balance enough for subsistence.[12] As pointed out by Dr Tara Chand, ' The policy was suicidal for it killed the goose that laid the golden eggs. It left no incentive for increasing the production or improving the methods of cultivation.'[13]

This policy was clearly enunciated first by Alauddin Khilji (AD 1296-1316) who argued that, as wealth encouraged defiance, if people could be impoverished, 'no one could even have time to pronounce the word "rebellion".'[14] Originally intended against potential rebels, these measures were progressively directed against all sections of the population, including the poorest of the peasants.[15] The policy was pursued by subsequent rulers even to the end of the seventeenth century.[16] Aurangzeb's instructions were that ' there shall be left for everyone who cultivates his land as much as he requires for his own support till the next crop be reaped and that of his family and for seed. This much shall be left to him, what remains is land tax, and shall go to the public treasury.'[17]

Alauddin's market regulations and his policy to keep prices 'low' and 'fixed' also affected the peasants adversely.[18] Such a policy killed the incentive to production and impoverished the producers. The policy was adopted by subsequent rulers.[19] Some other administrative measures also worked to cripple the incentive for greater production.[20]

In this period there was no institution or practice which could have countered the baneful effects of state policy, provided impetus for increasing production, and effected changes in the techniques of agriculture. The pessimistic overtones of Indian philosophy, imbibed by the common man, and the vagaries of nature had turned the peasant into a convinced fatalist reconciled to the worst sufferings of life.[21] Migration or flight was his first and natural answer. There was no effort to face the situation or make improvements.[22]

The social reformers and saints of the period only strengthened the passive approach of the people. By 'their emotional abandon and mystical rapture', they provided 'the most insidious escape from the realities of life'.[23] They never paid any attention to material conditions of life. They did not expose the economic ills or inspire the common man to fight against his economic exploitation, to shake off his poverty or to better his economic prospects.[24]

To be fair to the rulers of the period, however, one could not expect much direct effort on their part to bring about changes in agricultural techniques. As pointed out by K.M. Ashraf,[25] 'any big improvement in the method of production, a more equitable distribution of the economic wealth or a better adjustment of the economic position of the various social classes, was outside the policy of the state.' The Sultans and the Mughal emperors did initiate measures for the welfare of the cultivators and relief in times of extreme distress, like drought and famine,[26] but they did not introduce any significant change in the techniques of agriculture that could have increased the average yield. In the case of expansion in the area of cultivation, there was no effort on the part of the state to increase the fertility of the soil or to maintain and restore it. Even in respect of the canal system, developed by the medieval rulers, the motive was seldom to extend cultivation; generally it was to provide a safeguard against drought and a means for improving the crops.[27]

In the absence of comparative demographic figures for different regions and periods, we cannot determine the pressure on the land. Evidences that could indicate reclamation of new lands in the medieval period are wanting. Irfan Habib[28] infers an increase in cultivation since Mughal times, of which there were three main regions of the greatest increase. The first, comprising Allahabad, Oudh, Bihar and parts of Bengal, witnessed reclamation of the Tarai sub-mountainous forests. The second comprising Berar saw clearing of the central Indian jungles. Only in the third, the Indus valley was the extension due to the new canal system. But there is no indication of a corresponding increase in the average yield of the land. This was due to the practical absence of manuring.[29] Moreover, the extension of cultivation generally involved inferior land, uneconomical to sow, or clearings in the forests whose fertility had gradually reduced to the level of ordinary land.

State and Agriculture

There is a close connection between State and the forms and fortunes of agriculture. Political peace and stability is conducive to agricultural prosperity. In earlier times the State also participated in agricultural activity. Its vast resources enabled it to adopt improved techniques and undertake innovations. The State promoted agriculture by providing facilities which required huge resources.

We do not have evidence to indicate all the cases of introduction of new and improved techniques through State efforts. But evidence does confirm the facilities which the State provided to improve agricultural production. Here the major effort was in the direction of irrigation.

We cannot delineate the various stages in the expansion or shrinkage of agriculture caused by political factors in different regions. Political disturbances, wars, invasions and the indifference of the State could easily be expected to have dislocated and hampered agricultural work. Likewise, a realization of its own interest led the State to promote agriculture in a number of ways. To illustrate, we may point out that contemporary records testified to the adverse effects of protracted wars between the French, the British and the Indian rulers in the later half of the eighteenth century, as evidenced by untilled lands, deserted villages and ruined tanks in south India.[30]

It may be noted that in western India, under the Peshwa rule, the 'policies and style of administration' resulted in a steady and gradual expansion in the tillage area throughout the eighteenth century. But in the closing years of the Maratha rule and the early years of the Company rule there was a perceptible diminishing of the area under cultivation.[31]

In eastern India, there was a marked process of dislocation in agriculture. In Orissa the decadence was pronounced and was, to some extent, due to the Maratha occupation. In Bengal and Bihar the scarcity of labour and the impoverishment of many zamindars were constraints to the growth of cultivation. The famine of 1769-70 accentuated the process of decline. After the 1780s, there were increasing signs of growth of cultivation resulting from the reclamation of the abandoned land, a natural growth of local population, the short-distance movement of the peasants, the migration of tribal labour, and the liberalization of the terms of revenue.[32]

The coming of the Europeans promoted the cause of agriculture in a number of ways. The development of natural history and botany in Europe caused the European administrators, missionaries and doctors to take a scientific interest in the Indian flora. Garcia da Orta (1479-1570), the Portuguese physician and botanist, made a scientific study of the flora of western India. Heinrich van Rheede tot Darkenstein (1637-1692), the Governor of the Dutch Possessions on the Malabar coast, published his *Hortus Malabaricus* in 12 volumes, which provided Karl Linneaus, the renowned botanist, the base for the nomenclature of Indian plants. On the Madras coast the real pioneering work was done by Johan Gerhard Koenig (1728-81), a Dane, who was later appointed the Natural Historian of the East India Company. He formed The United Brothers, a group for promoting botanical studies. Soon the botanical interests of the group reached the Bengal Presidency.[33]

The commercial interests of the Company encouraged the study of economically important plants. In furtherance of the same the Royal Botanical Garden (now renamed as the Indian Botanical Garden) 'was established with fourfold purpose of conferring economic benefit to the region, increasing their resources in food and raw materials, importing from other parts of the world newer types of plants of economic importance, and acclimatizing them here, as well as for extending the interesting science of natural history and particularly botany.'[34]

The garden was established first at Sibpur in 1787. Its activities expanded under Robert Kyd, the first Honorary Superintendent of the Garden. He introduced some 300 species and advocated the establishment of a nursery stock of plants. He grew several kinds of economic plants. The Company promoted the cultivation of cinnamon as being commercially beneficial.

The Asiatic Society (later rechristened as the Asiatic Society of Bengal), established at Calcutta in 1784, had a wide range of objects.[35] William Jones, its moving spirit, included in it researches into Indian agriculture. William Jones was himself interested in botany and made significant studies on Indian plants. Several members of the Society made investigations into the rich flora of India. But the company did not initiate scientific study of natural history. Charles Grant, one of the directors of the East India Company, in making a plan for imparting western education in his famous treatise written in 1792-97, advocated the application of mechanical contrivances for improvement in agriculture.

Under Roxburg, the Indian Linnaeus and the father of Indian Botany, the Botanical Garden made botanical investigations and promoted commercial plants. His catalogue of plants *Hortus Bengalensis*, 35 volumes of coloured illustrations of plants, *Flora Indica* and *Plantae Coromandeliance* served as the basis for subsequent studies on Indian botany.

However, the eighteenth century did not witness any significant activity in the specialized area of agriculture. The establishment of learned societies, the creation of government departments, and projects for researches into various aspects of agricultural activity had to wait for the nineteenth century for any systematic effort to surface. Separate institutions for imparting agricultural education appeared very late in the nineteenth century.

Semi-government agencies were also involved. An agricultural society was formed in Calcutta. It aimed at correcting the defective practices and promoting diffusion of scientific knowledge. It contemplated the introduction of new and useful plants and improvement of implements of husbandry and stock.

It was realized that India was rich in grains and plants and did not need the introduction of new plants. But opportunities for accepting new possibilities, even in regard to food and fodder for cattle, were utilized. Thus a private person obtained seeds of clover from Bussara and sowed them with great success near Kaira in Gujarat. In army cantonments, lucerne and carrots were cultivated.

III. TOOLS AND TECHNOLOGY

In criticizing Indian agriculture for its backward and stagnant character, its tools and implements were described by Europeans as being primitive, crude and imperfect. To illustrate, Buchanan noted that 'the plough has not penetrated above three inches deep, and has turned over no part of the soil...The plough has neither coulter nor moulboard, to divide, and to turn over the soil; and the handle gives the ploughman very little power to command its direction.'[36]

The government made serious efforts to improve the condition of the cultivator. It tried to bring new techniques and tools to the cultivator. English ploughs and other implements were introduced in Salsette, but were rejected being too costly and too heavy and less functional. It was recognized that the Indian plough, though simple in construction, was light and was suited to local requirements, the soil and the crops concerned.

On the basis of observations and on the spot study, some experts commended the Indian practices as 'founded on the most enlightened principles of modern farming', in terms of ploughing, manuring, transplanting and rotation of crops. They realized that the Indian cultivator was not averse to change and improvement; he appreciated his requirements, though at times he might be impeded by want of funds.

There were instances to show that the Indian cultivator did experiment with new methods. Thus, many cultivators in the Thana region gave up their traditional ways of rice cultivation and adopted the Gujarat method in the last quarter of the eighteenth century. The new method not only saved the quantity of seeds to be used but also resulted in increased output.[37]

The main reason for the Indian farmer not adopting new techniques or implements was his poverty. He did not have the means to pay for these. He suffered from 'a sense of economic insecurity'. He did not dare to experiment with innovations. He aimed at the minimum of subsistence, which was guaranteed by the existing practices. The State policy of taxation did not provide him any incentive to increase his yield through improved technology.

Notwithstanding the criticism of Indian farming technology as backward, it is interesting that the yield per acre in the seventeenth and the eighteenth centuries was very high.[38] The figures supplied by Dr Tennant[39] could have been higher, as the peasants who gave the information were prone to understate the yield of their fields. The lower figures here compare favourably with those for mid-nineteenth century UK, with its scientific cultivation. Even admitting the explanation that the Indian practices were wasteful of seeds and that with the lesser pressure of population only the more fertile land was used, the fact remained that Indian technology, with all its shortcomings, was effective and resulted in high yields.

The importance attached to ploughing explained a number of rites performed for its success in various regions. The *Kṛṣi-Parāśara*[40] referred to the auspicious rite of *halaprasāraṇa* (commencement of ploughing), with details of the time and method of ploughing. Though it referred to astronomical considerations, they had little practical applicability and smacked of superstition.

The plough used in the period could not have been different from those prevalent in the nineteenth century. The *Kṛṣi-Parāśara*[41] and the *Mānasāra*,[42] a text on architecture, which could be placed in the early part of the period, gave a detailed account of the component parts of a plough along with their measurements. In the *Kṛṣi-Parāśara* the parts named were the yoke (*yoga*), the pins of the yoke where the bullocks were tied (*aḍḍacalla*), the pole of the plough (*īśa*), the plough proper (*niryola*), the piece of wood fixing the *niryola* to the pole (*śaula*), the plates fixing the ploughshare to the *niryola* (*niryola-pāśikā*), the strong piece of wood fixed to the *niryola* at the other end (*halasthāṇu*), the bamboo goad with iron top (*pañcanī*), the iron rod for preventing the *niryola* from falling out of the pole (*ābandha*), the tie yoke (*yoktra*), a rope and the ploughshare (*phāla*).

Against the general impression that the drill plough was a modern European invention, Thos Halcott, towards the close of the period, found a drill plough in general use in some parts of south India, and was informed about its use since times immemorial.[43] A drill plough was implied by Pāṇini,[44] but we do not know its form and functioning in the earlier times. Halcott testified that the drill plough, though simple, had an advantage over the patent drill plough in dropping the grain equally. It had three teeth about 18 inches long and 10 inches asunder. A hollow bamboo 3 ft long and an inch in diameter was inserted through the upper end of each tooth, near the back. The upper ends of the bamboos where brought close in the form of a triangle and inserted through the bottom of a wooden cup. The apparatus was held steady by cords. The cup was constantly fed with seeds by hand.

The *Vṛkṣāyurveda* of Surapāla had a separate section (verses 35-44) on determining the type of ground (*bhūminirūpaṇa*). It classified land into three types: dry or arid (*jāṅgala*), wet (*anūpa*) and moderately humid (*sādhāraṇa*); and it listed the trees that grew on them. It introduced classification on the basis of colour (*varṇa*) and taste (*rasa*) of the soil, mentioning six types each of the two.

In the section on plantation of trees (*vapanavidhi*), *Vṛkṣāyurveda* advised about the land on which to plant, the distance between the plants, the pit in which to plant, and the months in which to plant (verses 63-69, 87-90). But the text did not pay any attention to the layout of gardens.

The text mentioned three ways of planting plants (*pādapa*), including big trees (*vanaspati*), trees (*druma*), creepers (*latā*), and thickets (*gulma*) by seed (*bīja*), scion of a plant (*kāṇḍa*), and bulbous root (*kāṇḍa*) and listed groups of plants that grow by these methods. It described in detail the treatment of seeds. The seed was to be extracted from a fruit that had ripened in season and dried. It was to be soaked in milk, besmeared with the ashes of Bṛhati, sesamum and ghee, and rubbed well in cowdung. It had to be dried in shade for five days, then rubbed repeatedly in honey and the powder of Viḍaṅga or in the ashes of Bṛhati, sesamum and Nala mixed with mustard, and then fumigated with ghee mixed with Viḍaṅga, or with fat.

The *Kṛṣi-Parāśara* instructed that for further use (verse 157-67) the seeds of rice were to be collected either in Māgha or Phālguna and dried up thoroughly in the sun. The chaff was to be removed and uniform seeds were to be collected and kept in a very light packet. The grass that came out was to be cut. The advice in the text contained much with little practical usefulness, being based on traditional notions of sacramental purity.

IV. AGRICULTURAL CROPS

The geographical variations in different parts of India, in terms of soil, climate and availability of water, have favoured the cultivation of a wide variety of crops. Ancient texts yield the names of a large number of grains and cereals. These crops continued to be cultivated in later periods.

The various crops, their geographical distribution and the techniques of their cultivation do not show any remarkable change or improvement which could be identified as direct borrowing or influence of central Asia or as caused by the personal interest of the rulers.[45]

Cereal Crops

Wheat was the main crop in north India and was grown in all the *subās*—Allahabad, Oudh, Agra, Delhi, Lahore, Multan, Ajmer and Malwa. Considering the long history of its cultivation, it is natural to expect that several varieties of wheat suited to the geographical and climatic peculiarities of various regions would have evolved; but, in the undeveloped stage of agricultural science, they were never accorded separate identification. Wheat is known to have been grown in Bengal also, but we do not know its specialities as distinguished from wheat grown in other places. Wheat was cultivated in Qandahar as well. It was evidently of a distinct variety, being extremely white in colour.

Jgu (*jav, barley*) was grown in all these regions where wheat was cultivated. It was the main crop from the very early times. But gradually its primacy was snatched away by wheat. In this period, wheat cultivation was three times that of barley. Barley was not cultivated in Assam, Bengal and Orissa, which were predominantly rice-growing areas. The *Ain-e-Akbari* records that barley was grown roughly over one-fifth of the entire cultivated land. We do not find any reference to the characteristic differences in barley cultivated in different regions.

The transplantation method for cultivation of rice had been known at least since the times of the Buddha. The long experience in rice cultivation resulted in an advanced knowledge of this crop and in the development of a number of varieties suiting different geographical and climatic conditions. The *Kṛṣi-Parāśara* described the technique of agriculture with rice as the main crop. Rice was cultivated in many parts having high temperature and water-logging. The *Ain-e-Akbari* mentioned three varieties of rice cultivated in the *subās* of Agra, Allahabad and Oudh : S*hali mushkin* (dark-coloured rice), *Munj* rice (related to the present *Basmati* variety), and the common rice.[46] Oudh was famous for its *Sukhdās, Madhkar* and *Jhanwār* rice, which could be scarcely matched on account of their 'whiteness, delicacy, fragrance and wholesomeness'. *Sukhdās* rice was known for its high quality and special flavour. Bengal was renowned for its rice cultivation, in terms of both large quantity and variety of kinds produced. Of its several varieties *Kar, Sukhdās* and *Shali* were the superior ones. The *Ain-e-Akbari* mentioned one variety of Bengal rice which 'is sown and reaped three times in a year, on the same piece of land with little injury to the crop'.[47]

In respect of rice cultivation the importance of Bihar was next only to Bengal. The *Ain* recorded that the Bihar rice 'for its quality and quantity is rarely to be equalled'. Khandesh and Kashmir were also known for their rice of fine quality. The *Mir'at-i-Ahmadi* (mid-eighteenth century) claimed an improvement in the quality of rice raised in Gujarat. Other areas producing good quality rice were Orissa, Delhi, and Lahore. But in all these cases we are not informed about the different peculiarities of the rice of these regions.

The records of taxes realized from various crops in Akbar's time indicated the categories of grains and cereals produced. Among these were a number of small-grained cereals that could be grouped under the general name of millet. These were generally cultivated in regions with a dry climate. The list included *Jowar* (Sorghum, Joar, great millet), *Shamakh* (Sanwa, Japanese millet), *Kodron* (Kondo, Kodo millet), *Gal* or *Kunguni* (Kangri, Kangu Kunkum, Italian or horsetail millet), *Arzun* (Chin, Morhi, Anu, common millet), *Manwah* (Mandua, Mandal, Ragi finger millet), *Lahdarah* (Bajra, Bubrush or pearl millet), *Kudiri* (?) and *Barti* (?).

The millets were the main items of consumption by the poor, or else they served as fodder to cattle. J. Xavier testified that in Agra region millets were the common food of the common people. Of the various millets, Bajra did not seem to have been cultivated very extensively.

The records about taxes mention a number of leguminous seeds which were used as pulses. These included *Maash* (Mung), *Maash siah* (Urd), *Moth* (Meth Kalai, Kheri), *Lobya* (Cowpea), *Kult* (Kulthi, horse gram), *Adas* (Masur, lentil), *Nakhud* (Chana, gram, chick pea), *Mashang* (Mathar, garden pea) and *Khesari* (grass pea).

Other Crops

In the revenue records, all the seeds yielding oils were grouped as one, even though they were not of the same species and variety. Under this category the important crops were those of linseed, safflower and *Til* (Sesame). *toreya* also yielded oil. Under mustard were included both *Sarson* and *Rai*. The main species mentioned were Kalisarson, yellow Sarson, Safed Rai (white mustard), Rai and Kali Rai.

The *Ain-e-Akbari* mentioned two fibre-yielding plants, hemp (*sun*) and jute. Of these, hemp was cultivated more extensively. Jute was cultivated in Bengal for local use only.

Maize or *Makka* is generally taken to have been introduced from America. But there is no authentic evidence about the history of its coming to India. It has been suggested that this was possibly some time before Aurangzeb. Collection of tax from Makka was mentioned first for the pargana of Chatsu since 1664 and then from Jaipur since 1689.[48] The origin of Makka is still debatable. The availability of wild maize in Assam and archaeological evidence of its association with protohistoric potsherds from central India make a case for its being known since very early times. The absence of positive evidence for its cultivation in the long gap of 1,600 years could be explained in several ways. Maize was a poor man's crop, used also for feeding animals, and hence earlier it was not considered an item fit for regular taxation.

The very name Kabuli for a kind of gram (*nakhūd*), different from Hindi, mentioned in the *Ain-e-Akbari,* suggests its origin.

On account of central Asian influence the medicinal use of some plants went up. Of these, the most notable was the Henna or *mehndi,* which possibly came into popular use in the medieval period; otherwise, the ancient literature in India had no mention of this dye yielding plant.

Among narcotic plants, opium and true hemp (*bhang*) were in use, though forbidden by the imperial orders of the Mughal rulers.[49]

Tobacco was introduced in the reign of Akbar by pilgrims returning from Mecca. It does not occur in the *Ain-e-Akbari.* During Jehangir's reign its popularity with the peasants affected other crops and the prohibitory imperial orders were abortive. Soon its use became fashionable with the rich and the poor alike.[50] Manuci recorded its great consumption by the 'Mohamadans'. Its cultivation extended rapidly. By the middle of the seventeenth century it was grown in great quantity, even in remote inland areas of the empire.[51] The cultivation of tobacco suffered from a taboo. In Gujarat it was accepted as a commercial crop around the middle of the seventeenth century, but in the Deccan this was postponed to the later half of the eighteenth century.

The semi-urban towns, which arose around feudal chiefs, promoted a greater use of vegetables. The cultivation of vegetables in areas around towns was a noteworthy development during the period. An imperial *farmān* in the eighth year of the reign of Aurangzeb records that 'officials and government servants grow in their gardens and those of the Crown (*sarkār-i-wālā*) every kind of vegetable and fruit and give them to the greengrocers at double the rates.'[52] European travellers made a special reference to the 'variety and abundance of vegetables grown in India'.[53] The *Ain-e-Akbari* mentioned a number of taxable plants which were eaten as vegetable. The vegetables were of so many varieties that they were difficult to enumerate. Some other plant products, which were taxed, included water chestnuts (*singhārā*), turmeric (*haldi*), sprague (*ajwain*) and fenugreek (*methi*). It is interesting to note that chilli does not appear in the medieval culinary records.

The new emphasis on the cultivation of vegetables was reflected in the *Kāśyapīya Kṛṣisūkti* which mentioned vegetables as one of the principal items in agricultural activity.

India received a number of new crops and fruits from foreign countries especially during the medieval period, in the second half of the sixteenth century. Many such items were borrowed from South America. The Portuguese coming to the western coast were the main carriers of these plants and fruits.

In earlier periods these plants were confined to western India and had a slow acceptability. Of these, chillies and groundnuts soon became popular. The cultivation of groundnuts spread more in Gujarat, whereas chillies were more accepted in Deccan and Goa.

The period witnessed the introduction of potato and tomato. Initially, these vegetables could not gain common currency among both the nobles and the masses. The orthodox sections, especially the Brāhmaṇas, avoided the exotic potato. Its cultivation as a regular vegetable could be established only after the close of the period. Later potato received acceptance as an important and popular item in the list of Indian vegetables and came to be permitted for use on days of vows and fasts, as similar to fruits. The taboo against tomato among the orthodox sections persisted on account of its red colour, resembling blood.

We are not sure about the time and agency for the introduction of coffee. Coffee plantation in the south is evidenced from about 1665. But this was possibly of an inferior quality necessitating its import from outside. Abyssinia and Arabia were the two sources for its supply. During the later part of Aurangzeb's reign coffee had gained currency as a fashionable drink in aristocratic and higher social groups. The absence of any reference to coffee in *Ain-e-Akbari* suggests that the consumption of coffee was not appreciable enough to be noted. It was in 1830 that the first coffee plantation was started in Mysore.

Cash Crops

The importance of 'cash crops' of modern terminology was duly recognized in the medieval period. They were referred to as *jins-i-kāmil* and *jins-i-a' lā,* in contrast to *jins-i-adnā* and *jins-i ghalla,* which meant crops fetching low prices and included food grains. The former were raised mostly for sale, whereas the latter were mostly grown for local consumption. The absence of any explanation of those terms in contemporary literature implies that they were in general use and were clearly understood. Khafi Khan mentioned *jins-i-a'la* as 'sugarcane etc.' A late eighteenth century glossary of revenue terms included sugarcane, betel leaf, cotton, etc. in *jins-i-kāmil.*

Sugarcane as a cash crop has a high antiquity. The technicalities of its cultivation were known. There is a list of 12 varieties of sugarcane mentioned in *Suśruta Saṁhitā.*[54] In the *Ain-e-Akbari,* there is a reference to three varieties of sugarcane—*paunda,* black and ordinary.[55] The *paunda* variety of Ajmer was very highly priced, possibly because it was of a very good quality produced by the dry local climate. Bengal was the foremost on account of the quality of its sugarcane and also its extensive cultivation. Sugarcane was also cultivated in the area from Agra to Lahore. Other important regions were the sūbās of Allahabad, Oudh, Multan, Ajmer and Malwa. Sugarcane cultivation had extended to Aurangabad and some places in Bihar in the seventeenth century.

In terms of area of cultivated land, cotton was next to sugarcane. Cotton was cultivated also in many parts of the country which did not belong to the recognized cotton tract of volcanic and black soil. Besides Malwa, Khandesh and Berar, there were many centres of cotton in Gujarat.

Many other parts in the country were nearly self-sufficient in regard to their requirements of cotton. Cotton was grown in large quantities in many parts of north India, including Allahabad, Oudh, Agra, Delhi, Multan and Ajmer. It was also grown at many places in Orissa and Bengal. Bengal cotton seemed to be of a very good quality.

Indigo was an important cash crop. Besides its use in the country for washing and dyeing cloth and for paints, it was a profitable item of export. In Akbar's reign it was exported to Turkey and many European countries. Under Jahangir it became the prime commodity of export and remained very extensive and profitable under Shah Jahan, but declined after Aurangzeb. Indigo was extensively planted from Bengal to Khandesh. The Subās of Allahabad. Oudh, Agra, Delhi, Lahore, Multan, Ajmer and Malwa were known for their large output. The best quality of indigo was grown at Bayana in the present Bharatpur district. The second best quality came from Sarkhej near Ahmedabad. The indigo of Telangana was of medium quality. Aligarh, Khurja, Hindaun and Itimadpur also became important centres of indigo cultivation. The Bengal indigo acquired prominence in the seventeenth century.

William Finch (1608-11) gave a detailed description of indigo cultivation and manufacture. Indigo cultivation did not clash with the pattern of Rabi cropping and the interest of other crops. Though we could not be sure if the cultivators knew that the roots of indigo fixed nitrogen, they were surely aware that if indigo was not grown the fertility of the soil was adversely affected for growing spring crops. Indigo cultivation died out after the introduction of synthetic colours from Europe.

T. Raychaudhuri points out that by the mid-eighteenth century the subsistence character of Indian agriculture was affected by increasing commercialization, at least in some areas.[56] According to him, the tendency was indicated by 'the involvement of farmers with trade and of traders with farming, the extensive dependence of market oriented production on advances from buyers, the wide prevalence of rural markets and their links with the arteries of inland commerce, very substantial growth of non-food crop production and some tendency towards their localization.'

The market demand for certain agricultural produce caused expansion in the area of land under cultivation and shifts in crop patterns. In north India it was applicable for indigo, cotton and opium. Even then, as compared with the overwhelming commercialization in some parts of Bengal, the persistence of the existing pattern of crops showed that in the north the differentiation was substantial only relatively.[57]

In eastern India the shift to cash crops, though confined to a small area, was of much consequence.[58] Initially, commercial agriculture was promoted by European enterprise and grew with the requirements of international markets. Of the cash crops, tea plantation started growing around the close of the period, mostly due to the initiative of the government. There was an increase in opium cultivation on account of the interest of the government, which had exclusive control over its production and sale. Indigo was a new cash crop in Bengal. Its cultivation was promoted by the European enterprise as a promising substitute for the decline of trade in cotton goods. The government interest in an increased supply of raw silk encouraged an expansion in mulberry cultivation and the supply of silkworms of quality. The cultivation of sugarcane, an old crop, increased, especially because of the opening up of new markets. But the experiments with exotic sugarcane plants and plantations of the West Indies type proved a failure.[59]

The cultivation of cotton as a commercial crop in western India was promoted under the Peshwas. In the time of Madhavrao (1761-72), large quantities of Berar seed were imported for improving quality and increasing production of cotton in the Poona region. To meet the demand for good quality raw cotton for the textile industry at home, the East India Company arranged for the distribution of superior quality seeds in 1788. Experimental farms and experts imported from America could not establish the new techniques of cultivation. The experiment with exotic seeds—the New Orleans, the Upland Georgian, the Sea Island, the Bourbon, the Egyptian, etc.—proved unsuccessful as they did not suit the local conditions. The Bourbon variety was naturalized in Tirunelveli, Salem and Coimbatore, but Bombay and Berar were more suited for the new varieties.

The cultivation of indigo, an important commercial crop in many parts of Gujarat in the sixteenth and seventeenth centuries, was adversely effected by competition with the planters of indigo in Bengal and West Indies.

In south India, mulberry was introduced only towards the close of the eighteenth century, which resulted in a rapid growth in the production of raw silk.

V. HORTICULTURE

The culture of gardens received a fillip under Mughal emperors. On reaching Delhi, Babur remarked that Indians had not seen beautiful gardens.[60] But this should not cause any misgivings about the maintenance of gardens in earlier periods. Humanyun's appreciation of the layout of the gardens in Bengal was a testimony to the interest in gardens in the

Sultanate period. In ancient times the scientific study of plant life was done under the discipline of *Vṛkṣāyurveda*, which advocated a proper care of gardens.

The Mughal emperors were known for their keen personal interest in gardens. Babur raised a garden named as Hasht Bihisht or Nur-Afshan. His example was followed by Akbar, who made several beautiful gardens at Agra, Fatehpur Sikri and other places, the best being one around his tomb at Sikandara. The Mughal gardens reached their peak under Jahangir, who created beautiful gardens at all places where he stayed for some time. The most renowned examples are the Shalimar of Srinagar and those associated with the tomb of Itimad-ud-daula at Agra and his own at Shahdara near Lahore. The renowned gardens of Shahjahan included the Angoori Bagh of Agra, Shalimar Bagh near Lahore, and the one around Taj Mahal.

The *Ain-e-Akbari* pointed out that since the time of Babur's arrival 'a more methodological arrangement of the gardens has obtained, and travellers nowadays admire the beauty of the palaces and their murmuring fountains.'[61] The order and system introduced in the layout of gardens,[62] the digging of little canals with running water for the gardens.'[63] and the introduction of new flower and fruit trees were among the significant developments of this period. The engineering skills employed in the water-works of the Mughal gardens was of a high order, to which tributes were paid by European travellers. Thomas Roe observed that 'the king and nobility have as excellent and artificial water-works of their own as can be desired.'[64]

Firoze Shah Tughlak promoted the culture of fruit gardens very effectively, laying out some 1200 gardens in the Delhi area and 43 in Chittore. The practice of maintaining gardens of particular fruit-plants gained wider currency. Jahangir encouraged the culture of gardens by remitting the revenue if a cultivated land was converted into an orchard.[65] It was not uncommon for nobles, officials and even the Emperor to rent out their orchards to cultivators and professional fruit-sellers or to sell the fruits.[66] The Muslim nobles often built their graves in their orchards whose income was used by their descendants or the guardians of their graves.[67] The concern for the maintenance of gardens was possibly strengthened by the way of life then obtaining in central Asia, which became fashionable in India as well.

Babur introduced in his garden at Agra a variety of roses from Gwalior.[68] *Ain-e-Akbari* listed flowers of Iran and Turan available in India also: *Gul-i-surkh, Nargis,* violet, *Yasman-i-Kabud, Susan, Rayhan, Ra'na, Zeba, Shaqayiq, Taj-i-Khurus, Qalgha, Nafarman, Khatmi,* etc.[69] But it could not be ascertained whether these flower-plants came with Babur or had been brought earlier.

Literary texts confirm the care and concern bestowed on plants and their flowers. These plants had an aesthetic value as objects of beauty. The flowers were used for personal decoration, offerings to gods, and for preparing medicines. The *materia medica* texts (*Nighaṇṭu*) and lexicons of the period recorded names of a large number of flower plants. The *Vṛkṣāyurveda* of Surapāla laid down the special treatment to be applied to important flower plants for proper growth and efflorescence.

The *Genda* flower had a significance in religious offerings. Its origin was traced to South America. We have evidence of its presence in India even before the coming of the Mughals but we do not know as to how and when it was brought to India.

Babur named flowers which were not known to him before he entered India. These included *Chameli* (white Jasmine), *Gurhal, Kaner* and *Keora* (screw-pine).[70] Jahangir showed a closer familiarity with the flowers in India. He mentioned the places where he saw these flowers and in some cases even described the colours of their sepals and petals. Among these the flowers which were identified were *Kaner* (oleander), *Dhak, Nilufar* (Kumudini, lotus), *Kanwal* (Padma, Indian lotus), *Gul-i-champah* (Champa), *Gul-i-Keora* (Keora, screw-pine), *Rai bel* (jasmine), *Chameli* (white Jasmine), *Maulsiri* (Spanish cherry), *Seoti* (dog-rose), *Gul-i-bulanik* (crowned imperial lily), *Argwani Zard* (buttercup), *Nargis* (narcissus), *Banafshah* (violet flower), *Gul-i-badam* (almond flower), *Gul-i-shaftalu* (peach flower), *chhui-mui* (Lajwanti) and *Zaffran* (saffron).[71]

The strong perfume (*Atr*) of roses was first discovered by the mother of Nurjahan Begum. Jahangir himself has recorded it: 'The mother of Nurjahan conceived the idea of collecting the oil which rises to the surface when rose-water is heated.'[72] Very soon this *Atr* was accepted as one of the most powerful perfumes.

Babur was eloquent in praising the sweet and delicious fruits of central Asia. In his nostalgic obsession he condemned Indian fruits and lamented that the Indians had 'no grapes or musk-melons, no good fruits'.[73] These delicacies were considered to be an index of an elite way of life and, despite the difficulties of transport and disturbances caused by wars and political changes, were regularly imported from central Asia and neighbouring countries.[74] *Ain-e-Akbari* named the countries from where musk-melons, nashpati, babashaykhi, alisheri, alcha, barg-i-nay, dud-i-chiragh, grapes, cherries, seedless pomegranates, apples, pears, quinces, guavas, peaches, apricots, girdalus, aluchas, melons, etc. were brought all the year round.[75]

New fruit plants from central Asia and Afghanistan were introduced. During Akbar's reign, cherry was introduced in Kashmir from Persia. To improve local varieties grafting of superior stock was done. Shahjahan helped promote extensive cultivation of temperate climate fruit trees. Earlier their plantation was the preserve of emperors and noblemen.

Mango was the most popular fruit, but we do not find any reference to its then current varieties. Varieties of fruits, including grapes, dates. pomegranate, plantains, lemons, *Khirni*, jaman and jack-fruit were referred to by Amir Khusrau.[76] Babur mentioned many citrus fruits but their identity is difficult to determine.

Babur had listed a large number of fruits.[77] Jahangir also supplied us with an account of fruit trees.[78]

The Mughal rule witnessed the introduction of several fruit trees from South America. Guava (*amrud*) had become popular by the time of Akbar. In the sixteenth century the Portuguese brought pineapple to the west coast, but its plantation soon spread from Gujarat to Bengal. This required the creation of an artificial moist tropical environment, which, in the beginning, could be developed only in the imperial garden at Agra. Papaya and cashew nut plants were also introduced from South America, but, even in the seventeenth century, their cultivation was confined to the Portuguese possessions.

VI. IRRIGATIONAL FACILITIES

The proverbial dependence of Indian agriculture on the vagaries of nature, particularly on the uncertain and uneven rains, holds good for the period as well. Cultivators depended mostly on rains and the inundation by rivers. Babur described the rains in India with great admiration and observed that the Indians ' need not water-courses to construct dams because their crops are all rain-grown'.[79] Abul Fazl's silence about the provisions for irrigation in various provinces could be explained by the fact that 'the crops depended mostly upon rainfall and only partly on wells'.[80] Sujan Rai also said that in Hindustan 'most of the land is *lalmi*, which is synonymous with *barani* (i.e. dependent upon rain)', although he referred to land being watered by wells or inundations in some parts.[81]

Irrigation in Early Medieval Period

The early medieval period witnessed the composition of several works on weather-forecasting. Of these, only the *Gurusaṁhitā* has been critically edited. Some others, like the *Mayūracitraka* and the *Meghamālā*, are yet to be printed. These texts contained weather-maxims similar to those current in many regional languages. The authorship and the dates of the origin of the regional language maxims are difficult to determine. They represent the collective wisdom based on long experience and belong to an early phase in the development of languages. Though their scientific validity had not been investigated the Indian peasants depended on them for the rich practical wisdom stored in them. They present a strange mix-up of astronomical considerations and natural phenomena. The indications appeared to be superstitious in some cases, but were evidently based on careful observation spread over a long period.

The *Kṛṣi-Parāśara* showed how astronomical knowledge was used for forecasting rainfall in the interest of cultivation. Coming rainfall was guessed on the basis of the planet which happened to be the lord and minister of the year and the movement of planets from one zodiac to another. The nature of rainfall in various months from Pauṣa to Śrāvaṇa was determined on the basis of planets and natural phenomena. Certain natural phenomena and the behaviour of human beings, birds, animals, etc. were mentioned as indicating immediate rainfall.

The chapter on water-divining (*dakārgala*) in the *Bṛhat-saṃhitā* was possibly used in the period as the standard work on the subject. It was not developed further by any later scholar. Cakrapāṇi dealt with the subject in chapter 1 of his *Viśvavallabha*, borrowing many verses from the *Bṛhat-saṃhitā*. There was some elaboration and new information about the indicators of underground water, but, in the absence of texts of other authorities mentioned by him, we could not determine the extent to which the new details were based on Cakrapāṇi's own experience.

This specialized knowledge was of great use in constructing wells, tanks, etc. According to the *Kāśyapīya Kṛṣisūkti*, wells, ponds or tanks were to be dug after ascertaining the presence of water by an expert water-diviner. The text provided practical advice about the base, foundation, walls and the structure above the ground. The *Aparājitapṛcchā* gave an elaborate classification of reservoirs: ten categories of wells, two of small wells (*kūpikās*), four of *vāpīs*, four of *kuṇḍas* and 18 of tanks.

Tanks and irrigational works of high engineering skill were more in evidence in Deccan and the south, but examples are not wanting in the north. Lakṣmīdhara, associated with the Gāhaḍavāla court, mentioned a special type of reservoir called *dvārībandha* made by damming a mountain spring and thus forming a high level reservoir. Suyya, a minister under King Avantivarman of Kashmir, dammed the river Vitastā (Jhelum), built stone embankments for seven *yojanas*, and temporary stone dams at all threatened points and succeeded in shifting the junction of the river with the Sindhu to its existing position.

The *Kāśyapīya Kṛṣisūkti* is the only known Sanskrit text which discussed details of irrigational facilities. It emphasized the need for constructing a water reservoir near a village or town. This had to be near a hill or on a tablel and with a big lake and, in the case of a plain on a firm land, near a perennial spring. It might be fed with a mountain rivulet, a big lake, a forest brook, or a big river and should be provided with a suitable contrivance for distribution of water. There was to be a causeway and channels and sluices for filling and emptying it.

The Advent of Canal Irrigation

The text said that in the absence of the facility of a water reservoir a canal was to be provided. Such a canal could be one of four kinds, as it was fed from a river, a lake, a reservoir, or a mountain slope (i.e. a mountain rill). The feeding source of the canal was to be on a higher level than the region to be irrigated. At places, two or three canals were to be dug, according to requirement. The text gave practical details about the construction of a canal. The canals were to fall into a lake or a pond, or else to terminate as small culverts into the fields.

Under the Colas a very effective and efficient system was developed which empowered the village assemblies to arrange for distribution of water of the tanks and for their maintenance and repair.

The irrigation activity was promoted in a remarkable manner in the Vijayanagara empire.[82] This was primarily due to the personal interest of the emperors, of whom Bukka-I and Krishnadevaraya were the foremost. An idea of the huge amount involved could be had from the fact that, according to Nuniz, the expenditure in constructing the Tungabhadra dam made the treasury of Bukka-I empty. In this period many gigantic reservoirs, like those of Madag-Masur, Porumamilla, Kambum and Vyasasamudra, were built; several canals, big and small, were laid; and dams were raised on Tungabhadra and Kaveri at several places. Some of the dams were ingenious constructions. Some surviving tanks and dams are still in use. The example of the emperors was followed by members of the royal family, subordinate rulers and chiefs, and state officers. Local people, temple authorities and officers often cooperated in these activities. The name of Bayakara Ramappayya is remembered for having constructed the largest number of tanks. Sadasiva Nayaka (1512-46), a feudatory of Vijayanagara, constructed more than 14 tanks around his capital Kaladi.

The irrigational activity continued to be supported by succeeding families of chieftains who, with their limited resources and preoccupation with internecine wars, could muster only limited resources. The period from 1636 to 1799 witnessed long wars, which, in many cases, involved the destruction of irrigational facilities.

Bhattara Bachiyappa is said to have excavated a number of new tanks (*kannegare*) and made sluices to them. The magnitude of the irrigational work was indicated by the fact that in the Triyambakapura (Gundlupet) record dated 1417 alone, 18 tanks were named. The work required expert knowledge. One Singayya Bhatta, a hydraulic engineer (*jalasūtra*), mentioned as the master of ten sciences, well known for his skill, was commissioned to bring the Henne (Pennar) river to Penugonda.

Care was taken not to over-flood an existing reservoir if another was built near it. One gets an idea of the work involved from the Rajagundalahalli (Mulbagal) inscription of 1496, which recorded details of the construction of a reservoir, its sluices and the financial arrangements for its maintenance. The operation of the sluices was difficult and sometimes could be fatal. The use of inferior material could damage the sluices and render them unworkable. Epigraphic evidence referred to an officer to oversee the channel.

The maintenance of irrigational works; their repair and renovation received due attention. It was an important activity on the part of the Vijayanagara kings and their officers. If it could not be managed by local officers, higher officers used to take special steps. Besides involving the local community, influential people were encouraged to patronize such works. In many cases necessary financial arrangements were made for maintenance and restoration of irrigational work.

Irrigation Works during Mughal Period

The Turko-Afghan Sultans and Mughal emperors were alive to the irrigational needs and paid great attention to the digging of canals.[83] The first large-scale irrigation activity was recorded for the reign of Firoze Shah. Firishta attributed to him 50 dams across the rivers to promote irrigation, 30 reservoirs, 100 public baths and 10 public wells. The most important of these was a double system of canals passing through the vicinity of Karnal and entering the city of Hissar Firozah : one called Rajurah was taken from the Yamuna and the other called Ulughkhani was taken from the Satluj. A third canal terminated at the river Saraswati. The fourth, the forerunner of the modern Western Yamuna Canal, was the largest and came up to Hissar. The fifth connected the Saraswati and Makrand.[84] During the reign of Akbar the fourth one was repaired and re-excavated twice by removing the silt, first by Shihabu-ddin

Khan as governor of Delhi, who renamed it as Shihab Nahar, and later by Nuru-ddin Muhamad Tarkhan, who named it after Prince Salim.

Among the Mughal kings Shahjahan took great interest in canals. He repaired the silted Firoze Shah canal from Khizrabad to Safadon and then dug a new channel, 78 miles long, which was named Nahr-i-Bihisht, Nahr-i-Faiz or Shah-nahr, and was said to be 'something of an achievement' for its period, serving the needs of the new city of Shahjahanabad.[85] Another Shah-nahr in the Punjab was 84 miles long and stretched from the Ravi at Rajpur to Lahore. From Rajpur three other canals ran to Pathankot, Batala and Patti Haibatpur.[86] There were canals in other parts of the empire as well, some of which were excavated by government officials and chiefs. Ali Mardan Khan dug a canal from the Tavi to Sodhra near Wazirabad in the Upper Rechana Doab. Darya Khan, a minister of the Jama, excavated the Khan-wah in the Sind Delta.[87]

Not all the canals mentioned as dug by medieval rulers were new ones. Thus Firoze Shah's canal was partly an old channel, which carried the Chutang river to Hansi, Hissar and beyond, and it existed several centuries earlier, possibly since the eighth century.[88] Some of these canals were natural inundation channels, which were revived and sometimes extended. The silt was removed to put them back into regular use. The amount of care bestowed on canals was indicated by a long memorandum, drafted during the reign of Shahjahan, for clearing and deepening the channel of the Chutang or Chitrang river, so that its water reached Hissar.[89] In the Multan *sarkar* a canal superintendent (*mir-i-ab*) was appointed 'to dig new channels (*nala*), clear the old channels, and erect bunds on flood-torrents (*band-i-sail*)' and to distribute canal water equitably among cultivators.[90]

The canals, dug to populate a territory or to meet the needs of a city, could not have been confined to the drinking needs alone. They were in some cases referred to as meant for irrigating gardens or fields. In some sources there were pointed references to the benefits accruing to agriculture. As a result of the canals of Firoze Shah, cultivation of wheat and sugarcane was recorded to have begun in the area around Hissar and Firozabad.[91] Sujan Rai mentioned the great benefit accruing to cultivation from the Nahr-i Bihisht and the canals in Punjab.[92] Rice became the chief crop of the Indus delta on account of the irrigational facilities of the rivers. The 'high quality cropping' of Punjab and Sind, mentioned by contemporary sources, possibly resulted from the system of canal irrigation in these regions.[93]

Irfan Habib holds that the terms *araghaṭṭa*, occurring in ancient texts, signified a device which was noria, and that the Persian wheel proper, an innovation of the Arabs, was introduced in India in the thirteenth and fourteenth centuries.[94] We have shown that the device in ancient sources was similar to the noria in some cases, but in others it was nearer to the Persian wheel. There was no clear reference to a gear system in the device, but neither was there a reference to the rotation of the wheel through manual labour. For introduction of the *araghaṭṭa* device a date in second-third century might not be much beyond the mark. The *Upamitibhavaprapañcākathā* gave a detailed account of the device and its functioning.[95] It seemed to have come into larger use in the early medieval period. Being expensive it was not within the means of an ordinary cultivator and required specialists to operate it.

An eleventh century panel from Mandor (near Jodhpur) was taken to depict a Persian wheel, in which the gearing mechanism on the other side was not depicted in the profile presentation.[96] The testimony of Babur did not leave any doubt that the Persian wheel proper was in use in India long before he came to India, and that he had not seen anything similar to it outside India. Babur has to be given credit for making use of the Persian wheel or Rahat in some of his irrigational works. He vividly described all the essential parts of the Persian wheel as he found it being used in Lahore, Dipalpur, Sirhind and neighbouring regions

VII. MANURING OF SOIL

The constraints of sacramental purity did not permit the use of some very powerful manuring agents. Thus, whereas human ordure was carefully collected and used as manure in China and Tokugawa in Japan, the Indian cultivator could never think of using it. In the case of animal ordure, though its effectiveness was realized, the actual use was mostly limited to the ordure of cattle.

The cowdung was the most widely used manure. The *Kṛṣi-Parāśara* described the method of preparing manure out of cowdung by raising a heap of cowdung and, when it was dried in the sun, making smaller balls out of it.[97] The method implied an unexpressed appreciation of the fertilizing properties of cowdung and the way in which they could be preserved and increased.[98] The *Kāśyapīya Kṛṣisūkti* referred to a regular use of cowdung, goat-dung and compost.[99] The *Vṛkṣāyurveda* of Surapāla, in two sections, covering verses 97 to 164, gave detailed instructions about the preparation of manures and their application. There were a few general recipes, with some specific ones for particular plants. Besides dung, it recommended the use of fat, flesh, marrow, etc. of some animals, fish, Aṅkola, Viḍaṅga, sesamum and some other plants. The methods included direct application, besmearing, watering, sprinkling and fumigating with these items.

Considering the practice before the introduction of artificial and chemical fertilizers in modern times, one could not expect any improvement in manuring during the period. The ordinary cultivator generally used only cowdung and rubbish. Irfan Habib[100] postulated 'a more abundant supply of cattle manure' because of the larger per capita cattle population and easy availability of firewood on account of the extensive jungles. But, there was no indication that this improved cultivation in a noticeable manner.

The knowledge of two or more crop seasons had an early origin. But, this by itself was not sufficient proof of the application of the principle of rotation of crops. For this, we require clear evidence of varying crops on the same field in different seasons, so that the qualities lost in one crop were replenished in the following one, without leaving the field fallow to recoup the lost fertilizing elements. We could not expect a uniform practice, which varied according to the requirements, resources and knowledge of the cultivator and the qualities of the field in question. Nor could we search for a conscious knowledge of this principle. The available evidence did not permit a uniform generalization. The *Yuktikalpataru*, recently shown to be a fourteenth century composition, implied that the rotation system was not much in vogue. It said that the land lost fertility from cultivation year by year; when one plot of land lost in fertility, cultivation was to be done elsewhere. But Khanā, whose pithy sayings contained evidence about agricultural practices in the thirteenth century, suggested a knowledge of the system of rotation, when he observed:

> My worthy cultivator, plant radish towards the end of the third season of the year; sow mustard towards the end of autumn; and, if you mind to take money, sow maize in the following month of Caitra.

The *Vṛkṣāyurveda* had two sections, one on the diseases of trees (*rogajñāna*), verses 165 to 83, and the other on the treatment of their diseases (*cikitsā*), verses 184 to 22. It classified plant diseases in two groups—the internal or those arising from the body, and the extraneous or those attacking from outside. The internal diseases arose from the disorders of wind (*vāta*), phlegm (*pitta*) and bile (*kapha*) and the extraneous ailments were caused by vermin (*kīṭa*), frost (*sīta*), etc. The text detailed cures for trees suffering from internal disorders, infestation with insects, damage by frost and scorching heat, falling of branches, burning by fire, stricken by lightning and shrivelling by fire, sterile soil or want of water. It prescribed treatment for wounds, defluxion, diseases caused by wrong nursing, jaundice, barrenness and indigestion caused by water-logging.

There was a widespread practice of using magical spells (*mantras*) to ward off diseases, insects, birds and beasts from destroying the crops. This was evidenced from texts like *Kṛṣi-Parāśara, Vṛkṣāyurveda* of Surapāla, *Upavanavinoda* and *Jyotiṣtattva* of Raghunandana. The *Śārṅgadharapaddhati* referred to the throwing in the field sand empowered with *mantra*. The *Kṛṣi-Parāśara* advised the performance of the rite of planting a rod (*nalaropaṇa*), intended to remove all the ailments of the plants.

There is no evidence of any regular use of pesticides in the case of crops. The only reference occurs in the *Kāśyapīya Kṛṣi-sūkti* (verses 645-48) which prescribed systematic sprinkling of ash dust and lime water to remove the damage caused by vermin eating the leaves of such vegetables as egg plant (*vārtāka*), small cucumber (*paṭolikā*), *valtī*, pumpkin gourd (*kūṣmāṇḍā*), *surana*, turmeric (*haridrā*) and ginger (*ārdraka*).

John Fryer,[101] in the last quarter of the seventeenth century, described threshing by yoked oxen in the open fields as the practice of Muslims (Plough-man) and with stick as that of Hindus (Gentues). Irfan Habib[102] attributed the variation not to the faith of the peasant but to the kind of grain and the locality.

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61. Tr. Blochmann, I, p. 93.
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CHAPTER XIII

Irrigation in South India

T.M. Srinivasan

I. INTRODUCTION

Irrigation is the application of water or method of supplying water to crops in areas where the rainfall is scanty or comes in the wrong season. There are two types of irrigation, natural and artificial. The former is obtained through rivers, lakes, springs and rainfall, and the latter by human effort in the form of excavated tanks, lakes and wells. These two systems of irrigation were in vogue in south India from the Megalithic times (Iron Age), if not earlier.

In south India the practice of irrigation had its beginning in the use of naturally formed small lakes, pools and tanks for irrigating crops by the Megalithic folks. The Megalithic folks were settled people who practised agriculture as the main industry and knew the value and use of irrigation. Based on the *in situ* studies and archaeological evidences, it is quite plausible to ascribe the authorship of the tank irrigation system in the south to the Megalithic people. But in the historical period, the absence of perennial rivers coupled with the vagaries of the weather would have made it necessary that the rulers resort to impounding water in artificial reservoirs during the rainy season to create irrigation facilities for agricultural operations. Moreover, it was largely with a view to overcome the menace of years of monsoon failure and the resultant drought that the irrigation system of south India was conceived.

Importance of Irrigation

Tamil literary works indicate that the organized irrigation system began in south India as early as the initial centuries of the Christian era. Tiruvaḷḷuvar in his *Tirukkurṛḷ*[1] (sacred couplets) enumerated in unmistakable terms the important constituents of a kingdom: 'Water from rains and springs, a mountain here and water thence; these make a land with fortress sure and defence'. The *Puranānūru,* a Śaṅgam anthology, made a pointed reference to the importance of artificial tank irrigation thus: 'Verily he who has turned the bent (low) land into a reservoir to arrest the flow of the running water is one who has established a name in the world.' Apart from the above quotes from the early Tamil literary works on the importance of irrigation, we have a few medieval treatises on law written by many celebrated jurists. The most important personality among them was Vijñāneśvara who adorned the court of the Cālukya Vikramāditya-VI (*c.* AD 1075-1176). His famous work, *Mitākṣarā,* a commentary on Yājñavalkya, was an important treatise on law based on many earlier writings and had found acceptance in the whole of south India and large parts of the north. That the works of irrigation were looked upon as of fundamental importance was evident from the following injunctions contained in the *Miṭākṣarā*:

> When after obtaining the permission of the owner of the field either by request or by payment of money, a man who wishes to erect a dam for water, or sink a well, and if the owner of the field obstructs it, the owner himself is punishable.[2]

The essence of medieval thought concerning the great importance attached to the construction of works of irrigation is evident from the following quotation: 'The construction of a dam to a water flow should not be stopped by the owner of the field, even though it causes little injury and is productive of much benefit (to many).'[3]

The Āmuktamālyada a treatise on state policy written in Telugu by the Vijayanagar king Kṛṣṇadēva-rāya, stressed the importance of irrigation works in a *small state*:

> When a state is small in extent then both virtue (dharma) and prosperity (artha) will increase only when tanks and irrigation channels are constructed.[4]

Records on stones and metal have explicitly revealed the religious overtones and great social significance attached to the creation of irrigation works. Moreover, it is regarded as the greatest of the seven meritorious acts of man that are calculated to provide water, namely, giving water: *prapā, kūlya, vāpi, kūpa, padmākara, taṭāka* and *dam*. Inscriptions pertaining to irrigation works, while extolling the merits of such constructive activities, quote verses freely from the religious texts and other treatises of the period. One such is the *Porumāmiḷla* tank inscription of Bhāskara Bhavadura (AD 1369), a prince of the first dynasty of Vijayanagar, which quotes the following verses from Hemādri:

> A shed for distributing water (prapā), a well and a reservoir, a canal and a lotus tank, the merit of (constructing) them is millions and millions (of times) higher in succession (verse 26).
>
> As the water of a tank serves to nurture both movable and immovable creation on (this) earth, even the lotus-seated (Brahma) is unable to recount the fruit of merit (attaching) to it (verse 27).[5]

Throughout the medieval period the provision of irrigation facilities was regarded as the prime obligation of the State, and the rulers, particularly those without heirs, evinced a keen interest in affording these 'goodly works', for they constituted one of the *sapta śamtānas* (seven acts of righteousness). In one of the Kākatīya Gaṇapatideva (AD 1199-1262) inscriptions, the seven acts are enumerated as follows:

> He who possesses offspring in the shape of the following seven (acts) which (he) has duly filled: (the procreation of) a son, the composition (of a poem), (the hoarding) of a treasure, (the planting) of a grove, the marriage (of a girl to a brāhmaṇa), (the consecration of) a temple, and (the construction of) a tank (verse 43).[6]

The merit resulting from the construction of irrigation works is clearly set forth in a record of the sixteenth century:

> The gods, men, *pitṛs* (forefathers), the *Gandharvas, Uragas, Rākṣasas,* and the permanent *Bhūtas,* all depend on a tank. The person in whose tank, men, beasts and birds quench their thirst by drinking its water acquires the same merit as attached to performance of an *Aświamedha*. The *pitā* of the excavator of a tank rejoices, the *pitāmaha* dances (with delight) and even the *pitṛs* of his cognates join him.[7]

Apart from the above quotes, we come across a number of instances from the lithic records about the construction, restoration and repair of irrigation works. The importance attached to irrigation for the sustained fertility of the land in south India was unabatedly carried out by the state, philanthropists and private individuals. The material remains of irrigation works, some of them in a state of good preservation and use, bear ample testimony to the enterprising and devoted attention of the rulers and people of south India. It will not be out of context to repeat the words of Charles Trevelyan, who clearly observes,

> Irrigation is everything in India. Water is more valuable than land, it increases its productiveness at least six-fold and generally a great deal more and it renders great extents of land productive which otherwise would produce nothing or next to nothing.[8]

Forms of Irrigation Facilities

That the importance of irrigation was realized and shown in action is clear from a two-fold evidence. Firstly, records of the period mention a large number of instances of construction, maintenance and repair of such works. Secondly, the numerous remains of old irrigation works bear testimony to the care with which such facilities were created and attended to. Although there were different types of irrigation sources, like wells, reservoirs or lakes and river channels, they may be distinctly categorized under three broad heads: storage works or tank irrigation, river or canal works, and well or lift works. In addition, there are incidental but important works like the construction of embankments, tank bunds and sluice gates.

The principal systems that were extensively prevalent and practised in south India were river irrigation, artificial reservoir or tank irrigation and well irrigation. There was also a separate and independent system called the canal irrigation, without which water from rivers, branch channels and artificial tanks could not have been channelized and conveyed to distant lands.

Though the major river systems of south India might be traced to very great antiquity, it must be noted that due to constant deforestation and reclamation of forest and other waste lands into cultivable lands, the potential use of the then existing irrigation works was limited, and therefore, greater attention was paid to new storage works and digging of wells. It is, therefore, not surprising to note that tank irrigation accounts for the bulk of inscriptions relating to this period. Canal irrigation, too, is mentioned, but in a limited manner. It existed on the banks of rivers. Dams constructed across rivers enabled the canals on both sides to be supplied with water. From canals, small channels supplied water to the fields. From the rivers, feeder channels were dug to feed the nearest storage reservoirs. In the absence of facilities for such works, wells were dug and water taken by means of lifts (*piccotah*).

Well irrigation was suitable for small parcels of lands and garden crops. It may not be out of place here to refer to the opinion of Vijñāneśvara on the use of wells: 'A well, as it occupies a small portion of land, causes little injury but is beneficial on account of the abundance of water (in it) should never be stopped. The use of a well, moreover is indicative, by implication, of a small well, a water pond and the like others.'[9] Kambar, the author of the *Ērel̤upadu*[10] laid emphasis on the importance of the *ētta* (*piccotah*) in the following verse:

> Let not rain fall, let not kings rule the kingdom with justice. Let not each do his respective duty in the world. Let there be famine anywhere. Even if all these adverse circumstances happen at the same time, only if the peasants do their duty, water their corn from wells by means of *ēttam* (lift) the corn will grow and there will be no hunger in the land.[11]

II. CONSTRUCTION OF IRRIGATION FACILITIES

The problems regarding irrigation systems in south India, whether it was tank, canal or well irrigation, could be studied under three broad heads: (i) their construction; (ii) their maintenance and repair; and (iii) the distribution of water through them. Added to these problems was the traditional water management or administration of irrigation and water supply.

Agencies Responsible for Construction

The agencies responsible for the construction of irrigation works were the State, the village communities, private individuals, and temples.

The State had a considerable role in the construction of irrigation works. This was mainly due to the initiative of the rulers to provide irrigational facilities to their subjects in return for the various taxes collected and partly, to satisfy their personal desire to achieve distinction. We get a detailed account from the inscriptions of the rulers' anxiety to make available maximum irrigation facilities to the cultivators. This is further proved by the remains of old and extant irrigation works. It would be appropriate to quote the opinion of C.S. Crole in this regard:

> Many of them now abandoned or in ruins evince the solicitude of these monarchs for the extension of cultivation even in tracts not favoured by natural position or the quality of the soil. Almost every basin, however small, still bears traces of having been bounded across and in many instances this was done in order to secure a crop of paddy on a few acres of stony ungenerous soil to which all the fostering care of the British Administration has failed to induce cultivation to return. Large and extensive projects also were not neglected, some of which still bear witness to the enlightenment of these Hindu kings; while the absence of scientific instruments in those remote times compels the astonishment and admiration of the beholder.[12]

State help could be in the form of (a) grant of land for undertaking the construction of works, (b) remission of taxes on water and on land, (c) construction of works by the State, and (d) provision of funds for private initiative. Royal grants for digging canals and tanks came in the form of cultivable lands and the gifted lands were always free from the incumbency of taxes. Individuals who purchased waste or unclassified lands for irrigation works in public interest were exempted from payment of certain land taxes; indeed, the State often honoured the private benefactors in recognition of their services rendered by a grant of land. Such grants were either known as *daśavanda* or *kaṭṭu-koḍage*. The extent of the grant naturally varied with the importance of the work.

Village communities played no small role in creating of irrigation facilities. The normal course of action followed by a village community was to sell away some fallow common land of the village and to make a bund or dig a channel for the irrigation of some of the cultivable lands of the village. Sometimes, the construction was entrusted to a single village or a group of villages, and instances show that the villages had to bear the profits and losses according to the prevailing rules and conditions. The village community also sold land in their common possession for digging sacred tanks and wells for the benefit of temples.

Private individuals had an abiding interest in the construction of irrigation works. In this endeavour they always received unceasing encouragement from the State. Instances of such charitable works are numerous, often carried out by people on behalf of their kith and kin. It may also be mentioned that during bouts of acute famine, some individuals identified themselves with the famine-stricken people and undertook the excavation of tanks as a relief measure. Besides the construction of irrigation works, the private benefactors also gifted plots of land in their possession for the purpose of maintenance. Like the State and the village community, private individuals often constructed tanks, dug channels and built sluices for the irrigation of temple lands.

The temple's share was by no means insignificant and the inscriptions furnish eloquent testimony to the fact that they offered ample facilities for promotion of agriculture. It should, however, be noted that the temples did not involve themselves directly in this activity; instead, they bore the cost of construction and granted lands in their possession to interested persons to undertake such tasks. On certain occasions, temples made joint ventures with the *śabhā* (village assembly) to excavate tanks. Like the State, temples inspired private initiative by granting *inām* to the more active individuals who undertook famine relief work, and bestowed *daśabandha* or *kaṭṭu-koḍage* grants to them as a measure of encouragement for their involvement in this sphere of activity.[13]

Methods of Construction

Let us now look at the technical aspects of the construction of irrigation works. For the fulfilment of their task, the rulers and the concerned authorities employed engineers, consulted relevant treatises and applied different techniques and methods.

Irrigation as a scientific practice dealt with the systems of conveyance of water through channels. It also deals with the occurrence, quality and effects of water on the land area under irrigation. Epigraphy and literary works refer to this systematized practice as *'pāthas-śāstra'*.

Although regular treatises on this subject are no longer available, mention of the construction of irrigation works can be gleaned from a large body of south Indian inscriptions and, to a certain extent, from the accounts of travellers. It would, therefore, appear that special works on the science of hydrology existed in south India. Fortunately, the Porumāmiḷḷa tank inscription[14] (AD 1369) mentioned the 12 *sādhanas* (merits) of the Porumāmiḷḷa tank in particular and six *dośas* (defects) of tanks in general. This single unique epigraph testified that engineering in irrigation was well developed in those remote days. Besides, the *Viśvakarmā vāstuśāstram*[15] in Tamil also provides some details about the construction of reservoirs (for larger irrigation works) and wells.

There were specialists in the construction and execution of irrigation works. They were known as *Jala-sūtrada* (hydraulic engineers). We find references to them in the inscriptions only. We have two examples to highlight their achievements. First under the supervision of the Hoysala Baḷḷāḷa kings, the engineers brought the waters of the Yagachi river from the Halebid valley by a channel to supply the capital and fill the neighbouring tanks.[16] The second example comes from a record of the Vijayanagar King Bukkarāya-II (AD 1388). It relates to the accomplishment of the hydraulic engineer (*Jala-sūtrada*) Singāya Bhaṭṭa, who was the master of ten sciences *(Daśavidyā-cakravarti)*. He brought the river Henne (modern Peṇṇār) through a channel from Kaṭṭudi to the Siruvera tank at Penugoṇḍa and named it Pratāpa Bukkarāya Maṇḍala Channel.[17]

It is interesting to note that the engineers who had mastered the science of hydrology had also studied other sciences. From the records of the Cālukyas we learn that there was a separate department of water works *(vāri-gṛha-karaṇa)*,[18] under which many subordinate departments functioned. Perhaps, the engineers were attached to this department whose functions must have been purely technical, including the maintenance and repair of irrigation works.

Location of reservoirs: Reservoirs were developed to impound water to irrigate a large tract of land in the absence of natural streams and dependable channels leading off from them. Such artificial reservoirs were differently known as *ēri* and *āyam* in Tamil; *samudra, cheruvu* and *teruvu* in Telugu; and *kere* and *kereya* in Kannada. A public tank for drinking purposes was known as *ūr-uṇi-kuḷam* and a sacred tank for use by a temple was called *tirumañjana kuḷam* in

Tamil. The former was usually dug out in the centre of a village, while the latter was constructed as adjunct of the temple premises/complex.

The site selected for construction of a large reservoir by tank builders had to be in-between two mountains, for the mountain slopes on either side served as natural embankments. This sort of natural formation undoubtedly increased the storage capacity of the reservoir. In a mountainous country a reservoir could be easily built by merely joining a group of hills together by means of a stone embankment. This technique was possible only in places where such a natural formation was available. In other cases, different methods were employed varying with the terrain and locality.[19]

The magnificent Rāmappa lake constructed by the Kākatīya Gaṇapatideva in 1213 AD at a distance of 44 miles north-east of Warangal (Andhra Pradesh) was formed by a ring of hills on three sides with a colossal bund on the northern side.[20] The same technique was applied by the Kākatīyas in constructing a tank at Buddhapuri.[21] Another example is the Nāgalāpura tank built by the Vijayanagar Kṛṣṇadēvarāya, with the assistance of Joao della Ponte, 'a great worker in stone', sent by the Governor of Goa. The king built this tank to provide irrigation water to the fields and to the newly founded city of Nāgalāpura. Paes, the Portuguese chronicler, said that 'the King made a tank there as it seems to me has the width of a falcon shot and it is at the mouth of two hills so that all the water that comes from either side or the other collects there'.[22]

Constituents of a good tank: The Porumāmiḷḷa tank inscription defines the 12 essential *sādhanas* (merits) of a good tank and they are as follows:

> (i) A king endowed with righteousness, rich, happy and desirous of (acquiring) the permanent wealth of fame, (ii) and Brāhmaṇa learned in hydrology *(Pāthas-śāstra)*, (iii) and ground adorned with hard clay, (iv) a river conveying sweet water and three *yōjanas* distant (from its source), (v) the hill, parts of which are in contact with it (i.e. the tank), (vi) between these (portions of a hill) a dam (built) of a compact-stone wall, not too long (but) firm, (vii) two extremes (*śṛmga)* pointing away from fruit (giving) land *(phala-sthirā)* outside, (viii) the bed extensive and deep, (ix) and a quarry containing straight and long stones, (x) the neighbouring fields, rich in fruit (and) level, (xi) a water-course (i.e. the sluices) having strong eddies (*brahma*) on account of the portion of the mountains *(adri-sthāna)*, (xii) a gang of men (skilled in the art of its construction). With these twelve essentials, an excellent tank is easily attainable on (this) earth.[23]

According to the *śāstra* the following six faults or *dośas* had to be avoided in the construction of a tank: '(i) water oozing from the dam, (ii) saline soil, (iii) situated at the boundary of two kingdoms, (iv) elevations (*kūrma*) in the middle (of the tank) bed, (v) scanty supply of water and extensive stretch of land (to be irrigated) and (vi) scanty ground and excess of water'.[24]

Construction of reservoirs/tanks: After selecting the site, either in a hilly tract or in the plains, the bed of the reservoir in the basin system was strengthened with hard clay. Further, the entire area enclosed by a group of hills or earthen embankments was adjusted to form the bed of the reservoir. The elevation (*kūrma*) in the middle of the tank bed was totally avoided, because this could reduce the storage capacity. The bottom of the reservoir at the egress was formed of strong bed along a tortuous line, so that the water issuing from it whirled round with strong force, forming strong eddies. It was provided with inlet and outlet channels, the former normally three *yōjanas* distant from its source. In the basin system it was also the practice to carry the flood waters into the basin by means of canals. Main canals carried the water from the river. Distribution canals fed the water from the main canal into the basin. A dam across portions of the hills was constructed of a firm and compact stone wall. The stones from the quarry were straight and long to withstand pressure and strain. In the mountainous tract the question of an earthen embankment strengthening it with stone facing did not arise; whereas in the level plain it was necessary to throw up earthen banks all around the tank-bund.[25]

The Viśvakarmā vāstuśāstram[26] clearly deals with the construction of *taṭāka* (big tank) and *vāpi* (small tank). Big tanks were dug either in the middle or in the peripheral area of the village. Care was always taken that the site chosen had springs of good drinkable water. A well was usually dug in the centre of the tank. The tank was fitted with inlet and outlet channels for filling and discharging or emptying it. The tanks attached to temples were provided with a number of deep sunk wells *(uṛai-kiṇaru)* and a *maṇḍapa* at the centre, which was known as *nīrāḷi-maṇḍapa* in Tamil. Such tanks were generally provided with flight of steps, a covered verandah or corridors or platform all around and ornamental gateways on all the four sides. 'Small tanks may be square, rectangular or circular in shape and their dimensions may be from 3 to 6 *daṇḍas*. They are enclosed by walls and have springs on all the four sides. They are built down to a depth of about 10 cubits below the spring. They are also provided with bathing ghats on all the four sides, suitable for sporting in water. On one side of the tank shall be built a water-lifting device.'[27]

Small tanks *(vāpis)* provided with filling and discharging pipes and sluices were known in the early Tamil literature as *endiravāvi.*[28]

Construction of embankments: It is unfortunate that none of the various texts and inscriptions point out clearly as to how the embankments were raised. However, the reference[29] in the *Mahāvaṁsa* to the construction of banks of the Kāvēri by the Chōḷa Karikāla is confirmed in an eleventh century epigraph. It says: 'He (Karikāla), who curbed the pride of the subordinates, prevented the Kāvēri, which by its excessive floods, caused the earth to be deprived of its produce, by means of bund formed of earth thrown in baskets carried in hand by (enemy) Kings'.[30] This age-old traditional method of strengthening river banks is still in practice and being adopted in most of the riparian villages in south India. In the later centuries the river banks and tank embankments were either raised out of earth or reinforced with stone revetment. In some cases we notice in the records the use of granite, dressed and rough blocks, for the base of embankments.

Trees on the banks of tanks: In some places in Andhra dēśa, rows of trees called *kaṭṭava* were planted on or by the side of the bank bund, evidently with a view to adding to its strength.[31] In the Tamil country five fruit bearing trees—the Indian gall-met, Nelli, Tantri, Karanja-punga (Indian beach, *Pungania glabra*) and Aśvata (Araśu or fig tree)—were generally planted all along the bunds of tanks. The principle of planting such trees on the bunds of tanks was easily intelligible. The trees arrested soil erosion, due to breaches and sudden flash floods, and also held the water level which would otherwise fall without the banks. Hence, the presence of trees around the tanks was found very useful. Moreover, these trees yielded fruits which served as simple remedies for various ailments. Further, they contained some tannin in them which added a slight sweet taste to the water and thus masked any excess of chlorine in drinking water.

Construction of sluices: Sluices were contrivances in the form of gates or valves through which the water could be controlled or stopped. They were also used as surplus vents. For better flow of water from the reservoir, the sluices were usually installed at the points of maximum depth and quite far from the embankments. *Udagabandha* (Sanskrit), *kaliṅgu, madagu, tūmbu* (Tamil), *tubu* (Kannada), and *tumus* (Telugu) are the terms generally met with in the records of the period to denote a sluice.

Sluices were constructed out of stone; and sometimes the planks of palmyra trees joined together by means of ropes were also used as sluice shutters. The number of sluices required was determined and dependent on the size and water-spread of the reservoir. The extant *Vīrānam ēri* constructed by the Chōḷa Parāntaka-I at the fag end of the Kāvēri delta had 74 sluices. Likewise, the Cōḷagangam reservoir constructed by the Chōḷa Rājēndra-I was provided with several sluices and channels for the irrigation of a large area. The famous Pākhal lake constructed by the Kākatīya Gaṇapatidēva-I (AD 1213) had two sluices—Tower sluice and Sangam sluice. The water from the Tower sluice was let out into the surplus course and picked up by means of four pick-up weirs—Jalabandam, Thungabandam, Pasnoor and Veeraram—while the water from the Sangam sluice was directly released into the Sangam channel. Water meandered through five channels to a total length of 72.60 km to serve the ayacut.[32]

Head-sluice: We notice in the records the mention of a regulator, called the head-sluice *(kūrran-vāy)*. It was usually a strong piece of masonry work at a point where the canal took off from a river or a tank [and its purpose was to control the supply entering the canal. The Head-sluices are also known in Tamil as *nuck haray, talai-vay* and *Vay Halai.*]. Above the head-sluice was constructed a 'head of water' (*uvantṛi* or *talaippel̤ai*) with a large mouth or opening which conveyed the excess flow of water entering the canal from the main sluice.

A remarkable piece of native engineering work, which is still in a good condition and supplying water to the town of Tiruchirāppaḷḷi (Tamil Nadu), is the massive head-sluice of the Uyyakoṇḍān channel, a branch of the Kāvēri. This head-sluice was made of a solid granite block. It was erected about AD 1205-06 during the reign of Chōḷa Kulōttunga-III for conducting water into the Uyyakoṇḍān channel.[33] Another example is the head-sluice of the *Periya-vāykkāl* (big channel) on the northern bank of the Kāvēri near Musiri (Tiruchirāppaḷḷi). This head- sluice was spanned by a bridge across the channel *periya-vāykkāl.* On one of the side walls Chōḷa Rājarāja-III has recorded that in the eighth year of his reign (AD 1219), the head-sluice was built of stone at Musiri.[34]

III. THE TESTIMONY OF SKILL

The skill displayed in the construction of irrigation works by the tank builders of south India was quite remarkable. From the days of the early Chōḷa king Karikāla, the construction of banks on both sides of the Kāvēri was meticulously planned. The *Vīrāṇam ēri* created by Parāntaka-I of the imperial Chōḷa at the end of the Kāvēri in South Arcot district is one of the largest tanks in the Tamil country. The bund alone is 10 miles in length and has a mean width of about 3 1/2 miles. 'The circumference of the tank when it is full is nearly 25 miles. It is provided with 74 sluices and several channels and feeder channels. The overflow of the tank, "Cōḷagangam", at Gangaikoṇḍa Cōḷapuram, went to make the *Vīrāṇam ēri.*'[35]

Skill in Tank Construction

Of all the Chōḷa rulers, Rājēndra-I (AD 1012-44) alone was elevated to a place of eminence in history, for he celebrated his victories in the north by constructing a large reservoir called 'Cōḷa-gangam' in his new capital, Gangaikoṇḍa-Cōḷapuram (Tiruchirāppaḷḷi). His records refer to this tank as the 'liquid pillar of victory' *(gangajalamayam jayasthambam)* and briefly state that, 'This lord constructed in his own dominion as a pillar of victory (a tank) known by repute as Cōḷagangam which was composed of the waters of the Ganges.'[36] It has an 'embankment of 16 miles long, running north to south, and was provided with substantial sluices of great strength. The waste weir of the tank was just about the middle of the long embankment. The tank was filled partly by a channel from the Coleroon river, which entered it at its southern end, and partly by a smaller channel from the Veḷḷār on the northern end.'[37] Unfortunately, this huge tank has been ruined and become useless, but it still continues to represent the skill of the Chōḷa engineers and the solicitude of the ruler for the welfare of his subjects. A few records of Rājarāja Chōḷa-III (AD 1216-56) refer to a large reservoir, popularly known as Sembarambākkam ēri or 'Big tank'. It still exists and is 'one of the biggest irrigation tanks in the Chingleput district (Tamil Nadu) whose vast expanse of water, when it is full, is an object of attraction to the people in the vicinity, not to mention its immense utility for the agriculturist.'[38]

During the days of the Chāḷukyas of Badami, many irrigation works were carried out by the royalty. We learn that queen Vaayamati built a large reservoir which surpassed even the famous Sahasralinga lake of Sidharāja. Recent excavations have brought to light a channel about 300 feet long connecting the lake with the river Sarasvati, which evidently served as feeder channel to provide the lake with an abundant supply of water. Arrangements of stone-sluice gates to introduce water into the lake show the high degree of technical skill that the irrigation engineers of the Chāḷukyan period possessed.[39] Another important big tank was constructed during the time of Vikràmāditya-VI, according to a Kannada record from Kaṭṭagēri (Badami taluk, Katadgi). J.F. Fleet attributes three reasons for the sustained supply of water in the area after *in situ* inspection of the place:

> The system of tanks at Kaṭṭagēri was formerly a large one. First, there is a small tank, on the west of the Fort, and close under the wall which has recently been constructed as a famine relief work. Secondly, there is a large tank, on a slightly higher level—which if repaired, would, when full, include the proceeding in itself—formed by an embankment running to the south from just below the south-east corner of the Fort. And, thirdly, about a quarter of a mile away to the south-east of the proceeding, and on a lower level there are the remains of a larger embankment, now breached and quite useless, which when in repair, evidently formed a tank of very considerable area.[40]

It is discernible from the above account that the method of draining the surplus water from the tank at a higher level to the tank at the lower level must have been conceived and executed in this case.

In the Telengana region of Andhra Pradesh, the Pākhal lake, about 30 miles north of Warangal, is an outstanding testimony to the abiding interest of the Kākatīyas in the tank building activity. Constructed in AD 1213 by Jagadāla Mummaḍi, the younger brother of Gaṇapatidēva-I, the lake had an earthen bund 4430 feet long. It was carved out by harnessing a stream with an estimated yield of 1,877 mcft—1.75 times of the anticipated yield—either to absorb flood waters or to store for possible droughts. 'The low and high level sluices and the pick-up weirs prove how advanced their engineering skills were which have ultimately come to be considered as the model system even today.'[41] During the period of Paratāparudra Dēva-II, when the Mughuls invaded, a guard by the name Sitabkhan breached the bund *(gaṇḍi)* of the lake and it was subsequently filled. Since then the spot where the breach occurred has been, ironically, called 'Sitabkhan Gaṇḍi'. However, in AD 1902, the public works department of the Nizam restored the lake to its original glory at an estimated cost of Rs 4.5 lakhs.

This was one among the numerous lakes and tanks constructed by the Kākatīyas. It ought to be pointed out here that the ingenuity of the engineers of that era was followed by the Dutch engineers in constructing the 300 km long Kurnool-Cuddapah canal, off Sunkesula *ă´nicŭt*, during the 1860s.[42]

In the latter half of the fourteenth century, Bhāskara, alias Bhavadura, a prince of the first Vijayanagar dynasty, constructed a huge tank with many sluices about 2 miles to the east of the village Porumāmiḷḷa (Badvel taluk, district Cuddapah). It was elongated in shape, being 7 miles long and 2 1/2 miles wide. The bund consisted of four natural hills, connected by three short earthen dams, riveted with Cuddapah slabs. The western flank thus consisted of the range of hills which ran north and south between Porumāmiḷḷa and Badvel. The artificial bund, on its completion, was 5000 *rēkhadaṇḍas* long, 8 *rēkhadaṇḍas* wide and 7 *rēkhadaṇḍas* high.[43]

It is stated in an inscription that 1000 labourers were employed in its construction. It is also learnt from the record that the science of hydraulics *(Jalasūtra)* was well studied and applied by professionals while executing this magnificent tank. Even to this day the tank continues to afford irrigation facilities in the district.

Skilful Use of ă´nicŭts

During the times of Bukka-II and Dēvarāya-I (AD 1406-22) the city of Vijayanagar was substantially expanded. According to Robert Sewell, their 'great work was the construction of a huge dam in the Tungabhadra river, and the formation of an aqueduct fifteen miles long from the river into the city. If this be the channel that to the present day supplies the fields which occupy so much of the site of the old city, it is a most extraordinary work. For several miles this channel is cut of the solid rock at the base of the hills and is one of the remarkable works to be seen in India.'[44]

Referring to the *ă´nicŭts* constructed in the Vijayanagar period Major Henderson remarks that 'The proportion of the *ă´nicŭts* have been chosen with great judgement and the channels have been formed with consummate skill.'[45] The Portuguese traveller Nuniz had recorded the construction of the dam across the Tungabhadra with much detail. Recent studies have shown that the dam was actually a series of five or six small *ă´nicŭts* across a branch of the main Tungabhadra river. According to a report published in *Frontline* in December 1987:

> The *ă´nicŭts* today feed a channel called the *Turuttu* (meaning swift) which flows right across the valley for 11 miles, irrigating the surrounding fields. The *ă´nicŭts* have been strengthened in recent times but here and there part of the granite and mortar of the old structure is visible. The canal is remarkable and, like all water sources, has done much to beautify its surroundings. It follows the contours of the hills and in its construction huge rocks had to be cut sometimes. At least at one place along its course there is an inscription cut into the face of a huge boulder by a triumphant engineer, which tells us of the problems he encountered in breaking through the formidable boulder.[46]

From the sixteenth century, we have two important chronicles by Portuguese merchants who stayed at Vijayanagar, Domingos Paes (*c.* 1520-22) and Ferano Nuniz (1535-37). Their accounts written in about 1520 and 1537 respectively, give a contemporary account of the construction of a huge tank by Kṛṣṇadēvarāya near his capital to provide irrigation to the fields and supply water to the new city of Nāgalāpura founded by him. Paes says:

> The king made a tank there, which as it seems to me—has the width of a falcon shot—and it is at the mouth of two hills, so that all the water that comes from either one side or the other collects there; and besides this, water comes to it from more than three leagues by pipes which run along the lower parts of the range outside. This water is brought from a lake which itself overflows into a little river. This tank has three large pillars handsomely carved with figures; these connect above with certain pipes by which they get water when they have to irrigate their gardens and rice fields. In order to make this tank, the said king broke down a hill which enclosed the ground occupied by the said tank. In the tank I saw so many people at work that there must have been fifteen or twenty thousand men looking like ants, so that you cannot see the ground on which they walked, so many there were; this tank the king portioned out among his captains, each of whom had the duty of seeing that the people placed under him did their work, and that the tank was finished and brought to completion.[47]

Nuniz adds that the King made a bank across the middle of the valley so lofty and wide that it was a crossbow shot in breadth and had large openings. He made many sluices in connection with the tank and constructed many pipes to let out the water whenever necessary. Nuniz bears witness to the fact that by means of this project many improvements were made in the city and many new areas of rice fields and gardens were brought under cultivation.[48]

In a well-known later Tamil work *Śolamaṇḍalasatakam*,[49] mention is made of the construction of a stone *ă´nicŭt* across the river Kāvēri near Tiruchirāppaḷḷi by the legendary Karikāla Chōḷa of the second century AD. The work *Kallaṇai* in the text was misunderstood by many as the still existing 'Grand *ă´nicŭt*'. This is a solid piece of masonry work built of stone and brick. There is no conclusive proof that Karikāla constructed this 'Grand *ă´nicŭt*'. However, recent studies on the basis of contemporary inscriptions and later literary evidences place the construction of the *Kallaṇai* sometime in the Vijayanagar period (i.e. between AD 1310 and 1450). The *Kallaṇai* (grand *ă´nicŭt*), however, represented a major advance in engineering skill. It created the Kāvēri basin. Here a masonry embankment was thrown across a channel called the Ullār, which connected the Kāvēri with its tributary, the Koḷḷiḍam.

The *Kallaṇai* was basically a regulator that prevented the Ullār from draining into the Kāvēri. When the water level increased beyond a certain point, the surplus water dammed by the *Kallaṇai* was allowed to flow into the Koḷḷiḍam. Water was discharged during floods and on a regular basis during inundations. Thus, the *Kallaṇai* not only prevented the Kāvēri delta from being flooded but also from becoming swampy and water-logged. 'Its construction evidently presupposed a high level of knowledge, first, on the irrigational requirements of the delta and, secondly, on the kind of structural proportions that would make that level of regulated irrigation possible.'[50]

The *ă´nicŭt* is 1080 ft long, 40 - 60 ft wide and 15 - 18 ft high. Such technical skill, perfected over the centuries, won the admiration of some British officials and experts writing in the nineteenth century.

Sir Arthur Cotton, who was the then Chief Engineer of the Madras Presidency during the 1830s, had the foundation of the 'Grand *ă´nicŭt*' probed and found to his utter surprise that it had stood on foundations laid with large boulders embedded in the layer of stiff clay underneath the sandy bed. His experience with the Kāvēri works and his intimate knowledge of the 'Grand *ă´nicŭt*' encouraged him to construct the Dowleshwaram *ă´nicŭt* across the Godāvari, which is still serving and diverting the surplus water for irrigation in the fertile districts of Godāvari, both East and West. Writing in 1874, he noted with admiration that, while the British had been cautious about laying a foundation in shifting sand for the Ganges canal, the 'natives' had proceeded with boldness and engineering talent' to build weirs. These were built in: 'sandy beds of rivers without any rock or sound stratum to found them on ... He further added that 'the natives have constructed tens of thousands of tanks in almost every kind of soil with earthen bunds without the puddle bank which English engineers have fancied necessary'.[51] Horsley, the then engineer of the Pāṇḍyan canal, had observed:

> In other countries, and in India also an engineer generally works on his own lines in developing any large schemes of irrigation, and naturally credits his own skill and perseverance with the success of his undertaking. Here, however, I have no hesitation in saying that it has been an unmixed pleasure to me, from a professional point of view, to merely follow the lines of the original constructors of the Pāṇḍyan canal and Pulanabapooram Poothenaur, because the evidence of their skill and almost superhuman perseverance was so marked; and I have, in carrying out the works, felt contented and fully satisfied to follow in the footsteps of those whom I cannot but consider to have been masters in their art and *facile princeps* in irrigation engineering.[52]

It is, therefore, odd to view as serious the opinion of C.J. Baker who commented: 'Initial construction of ēri (reservoir) required no special technical knowledge; simply an eye for the lie of the land and a lot of humping of the earth.'[53]

IV. MAINTENANCE AND REPAIR

The maintenance and repair of irrigation works were as important as their construction. This is testified by a record of AD 1413 which recounts the merit accruing from such works: 'A ruined family, a breached tank or pond, a fallen kingdom, whosoever restores, or repairs a damaged temple, acquires merit fourfold of that which accrued from them at first.'[54]

Sources of Funds for Maintenance

Irrigation works deteriorated quickly due to two conspicuous reasons. The first was the accumulation of silt in the tank basin and the second, the occurrence of breaches in tank bunds and river banks due to heavy inflow of rainwater. The former could be attended to as a matter of routine work; but the latter required large funds to effect immediate action. Funds for such works were forthcoming from different sources: (i) the state and local assemblies; (ii) private individuals; (iii) the merchant guilds; (iv) the temples; and (v) the income from the tank reservoir itself.

State and local assemblies: Land was the mainstay of the medieval State economy. The land tax, collected by the state and local assemblies in the form of cash or kind or a mixture of both, was the chief source of revenue. A part of the land tax was set apart for maintenance and repair of irrigation works. As rightly pointed out by Burten Stein, 'one category of local revenue terms which looms large in the early records of south India relates to irrigation'.[55]

A brief review of some typical inscriptions of South India conveys a general idea of the nature and number of taxes, cesses and other dues levied for the purpose, and we are not surprised to find, especially in the inscriptions of the Chōḷas, more than 40 local revenue terms. The villages situated on the banks of the Kāvēri had to pay a small cess known as *Kāvēri-karai Viniyōgam* for the maintenance of the river bunds. The state and the local assemblies levied a cess on water drawn from tanks and wells, which was known severally as *nīr-vilai, nīr-sunga, nīr-kānam, Jalakara,* etc. Boatmen had to pay *ōdak-kūli* for plying their boats in tanks and the fishermen had to pay their professional tax for fishing in irrigation tanks. In addition, the land owners and tenants had to pay a small cess on water-lifts. Besides, the State and the local assemblies also collected certain toll revenue, cess on betel leaves, and fines for the tank use. In medieval Karanataka, for instance, the Kadamba rulers assumed the responsibility of irrigation facilities by presenting the *Mahājanas* of Nīrili the entire house tax of the place for the maintenance of the *periyakere* (big tank).[56] During the same period in the Tamil country a separate fund known as 'tank fund' *(ēri-mudal)* for the relief of irrigation works was established. Land taxes and fines on certain offences collected by the local assemblies were credited to this fund. Sometimes the recalcitrant villagers were forced to pay the local cess towards the 'tank fund' by the Tank Supervision Committee.[57]

Private individuals: From the inscriptions we learn that the maintenance of irrigation works was often undertaken by individuals as works of merit. The endowments made by them consisted mainly of gold, paddy, remission of certain taxes and dues, gifts of wet and dry land, and so on. The endowments and gifts were entrusted to the village governing bodies which utilized the proceeds thereof for the stated purposes. The maintenance of the Vairmeghataṭāka was a special feature of the administration of the *Śabhā* (assembly) at Uttiramērūr (district Chingleput) during the latter Pallavas and continued to be so in the Chōḷa times. The assignments of lands by the private individuals for such a public cause were known as *ēri-*

mānyam, ēri-ppaṭṭi, goḍage or *kaṭṭu-goḍage* and *kuḻappaṭṭi*. One noticeable distinction between *ēri-ppaṭṭi* and *ēri-mānyam* grants was that the former was set apart for the maintenance of irrigation works and the granted land and its proceeds were not free from taxes; whereas, the latter was tax-free land set separately for the same purpose.

Merchant guilds: In south India, there were several merchant guilds and corporations wherein the trading merchant communities were banded together. Some of the powerful merchants and traders owing allegiance to the guilds were also chieftains in their regions and they levied and collected certain taxes which they utilized for public purposes. An inscription[58] dated AD 1262-63, found on the margin of a well at Tiruveḷḷarai (Tiruchirāppaḷḷi), records that a merchant repaired it as it had suffered considerable damage from floods and other natural causes.

Temples: Among private agencies, the role of temples in the maintenance of tanks was sizeable. Affluent temples had surplus funds and landed properties and undertook directly or indirectly, to repair and renovate the village tanks for the public good. In emergency cases, the temple authorities helped the villagers by selling a portion of the temple lands and utilizing the proceeds for repairing the breaches in the village tank. In one instance, when a dam in a river breached and remained in a ruined condition, the temple authorities made a grant of land to certain individuals for repairing the dam so as to form a tank. Further, they were allowed to cut down the jungle, form a village, plot out fields, take three parts of the income from the village, and pay to the temple treasury the remaining one-fourth part.[59] In such cases, the temple expected the donees to keep the tanks in good repair. In certain specific cases, mutual agreements were arrived at on the basis of specific terms and conditions among the temples, the local assemblies and the individuals to conduct desilting operations for the village tanks. One of the conditions reported in a record (AD 1521) from the Tirunelveli district was that the residents had the right of fishing in the tank. They in turn agreed among themselves to remove a definite measure of silt every year from the tank.[60] Individuals who voluntarily repaired the irrigation works or offered their free services, were suitably rewarded by the temples as in the case of construction of irrigation works.

Income from tanks: Among the various sources of funds for the maintenance of irrigation works, the fishery lease money and the money realized from the sale of water were the two primary sources of income from the tank itself. They were not merely supplementary and additional but also a regular source of revenue for the local assemblies. In the inscriptions we come across various terms to denote the income specifically derived from the sale of fish or fishery-lease money. We have enough inscriptional evidence from the ninth to sixteenth century dealing with the maintenance of irrigation tanks through the fishery revenue.[61] Sometimes, the revenue was gifted over to the 'tank fund' or set apart for the exclusive purpose of the tank itself. The Vijayanagar rulers from the thirteenth to sixteenth century realized the importance of the fishery-lease money as a major source of income and utilized it exclusively for the benefit of irrigation works. This was attested by a number of Vijayanagar records. A study of these inscriptions indicated that the fishery-lease money was sufficient for the desilting operations and general upkeep of irrigation works in a particular year.

Another method by which resources were augmented by the State and local assemblies was the levying of tax on the water used. Terms like *nīr-vilai, nīr-kūli* and *nīrūkāṇam* are generally met with in the records to specify the water cess. There is no positive evidence to prove that the water charges were levied and collected on a uniform scale throughout south India. But it is beyond doubt that the water rate fixed by the local assemblies depended to a large extent on the ratio of distribution of water and the stretch of cultivable lands possessed by the ryots. These two sources were appreciable enough to meet the emergency needs and other routine work. In addition, the income from these two sources, to a certain extent, helped to swell the 'tank fund'.

Work of Maintenance:

The actual job of maintenance of irrigation works included among other things, the engagement of workmen, arrangement of tools, needed for the removal of silt from the tank beds and river channels, replacement of damaged sluices, prevention of breaches, repair of wanton damage done to the system. The details were, of course, well set forth in a few south Indian inscriptions. As regards the materials used for restoration of irrigation works, we could elicit very little information from them. The provision of free labour for such activities by the land owners and tenants was variously referred to as *amañji, amji, veṭṭi, veṭṭiyāl,* etc. Besides, there were the cartmen to carry men and materials, the boatmen to ferry the silt dredged from the tanks, and the fishermen to keep a vigil on the bunds and banks of tanks.

In AD 1367, provision for the maintenance of a tank in Arasikere (Karnataka) was made in the following manner:

> A buffalo man with his cart was permanently appointed for such work and it was ordered that for oil, wheel, grease, crow-bar, pick-axe, etc, every cart load of the original tenants had to pay two *taras* and likewise every load of arecanuts, betel and oranges had to pay at the same rate.[62]

In another instance, in AD 1513, when two tanks in the Chennapatna area (Karnataka) went into repair, a village was granted for maintenance, and it was ordered that six carts were to be kept, four for one, and two for the other, for putting earth on the bunds every year and keeping the tanks in good condition.[63] The Nellore records (sixteenth century) say that persons who belonged to such communties as the *Voḍḍars, Peddabôyas* and *Upparas* (diggers) were engaged to do the customary labour for the tanks. These persons were exempt from paying the usual taxes and dues, and they were provided with lands near the tank bund in return for the services rendered by them.

Use of boats: Records show that in medieval south India, boats of varying sizes were used for carrying the silt dredged from the middle of the tank to the tank bund. An interesting epigraph of the tenth century from Tiruchirāppalli (Tamil Nadu) gives details as to how the desilting operations were done and the expenditures incurred. According to the record 140 baskets of earth had to be taken out of the tank and deposited on the bund every day. Each of these baskets was big enough to hold six *marakkāl* which meant that about 200 cubic feet of earth was taken out every day. The establishment consisted of six labourers each of whom got one *padakku* of paddy every day for food and clothing; a supervisor who was given one *kuruṇi* and a half of paddy each day; a carpenter and a blacksmith for repairing the boats, each of whom got annually two *kalam* and a half of paddy; and the fisherman who supplied wood (for repairs to the boat) and got two *kalams* of paddy annually. The village had to get the land cultivated to meet all these charges out of the income. If they failed to do it the then reigning king could fine them and get it done. Altogether, provision was made for an expenditure of 412 *kalam* of paddy annually on the removal of silt.[64] This classic example shows the deep involvement of the entire village communmity in the desilting operation of the village tank.

Appointment of fishermen: Among the village servants the appointment of fishermen was perhaps a regular feature in the maintenance of tanks and dams. They were permanently engaged, and for the arduous task of looking after the tanks and dams, they were paid wages annually apart from the right of fishing in the irrigation tanks. The reason for awarding the fishing rights customarily to them was that the fishermen could live near the irrigation tanks and eke out a percarious living by fishing. We have very limited but informative references with regard to their duties. A Tamil record specifies:

> He should look after the dam and the channel, so that the water flows to the pond without running to waste, and in the case there was any deficiency of water in the dam

and the pond, inform the temple authorities and the villagers of this and with the help of the unpaid labourers (*Viṭṭiyāl*) of the village raise the dam and take care of it.

For this work, the fishermen received one *mā* of tax-free land and a specified quantity of paddy from the village.[65] We are not certain that such arrangements were made throughout south India.

Repairs: Periodical repairs to irrigation works was a regular activity of the local assemblies. But this also depended on the extent of damage caused to the irrigation works, whether by the fury of nature or by the acts of vandals. If the repair work was beyond the competence of a few village servants, the entire village rose to the occasion to meet the challenge. Of course, the State was the principal agency for carrying out major repairs, which other agencies could not do due to paucity of resources.

That the periodical floods in the Kāvēri had attracted and inspired the poets, is clearly reflected in the literature of the time. The lithic records also mention the floods and breaches in the Kāvēri and how they were subsequently tackled by different agencies. In AD 1401-03, the lands in some villages in the modern district of Thanjavur fell fallow on acount of unprecedented floods in the Kāvēri, which washed away the demarcation boundaries and silted the irrigation channels, leading to abandonment of the fields by the tenants. The government soon interfered, restored the channels and boundaries and rehabilitated the villages in question.[66] In this case the government had to take quick action, since it was presumably losing quite a good amount of land revenue. In another instance, in AD 1424, when the dam constructed across the river Haridra by Bukkarāya Nāgaṇṇa Voḍayār, the minister of Dēvarāya, was damaged, the village assembly got the necessary funds from Cāmanṛpala, the commander-in-chief of the army and soon restored the breached dam.[67] Such instances show that the action taken by the State was prompt in effecting urgent repairs to irrigation works at times of emergency.

Prevention of damage: Causing wilful damage to irrigation works was considered a heinous crime. Vijñānēśvara in his *Mitākṣarā*[68] compared persons who damaged reservoirs with those who caused the destruction of a child in the embryo and were guilty of manslaughter; and the punishment enjoined such criminals was to tie heavy stones round their necks and plunge them into the water, so that they might not float up. However, we have no recorded evidence to cite whether such capital punishments were ever carried out by the south Indian rulers or the local assemblies. But occasions were there, as a result of mutual feuds, when people at times caused damage to irrigation works. However, genuine attempts were made by the village community as a whole to prevent wanton and offensive acts on irrigation works. For example, we notice in a record of the Chōḷa Kulōttunga-III (AD 1223) that the residents of a particular village made a solemn agreement among themselves that they would not cause any damage to irrigation channels, tanks, wells, water-lifting devices, trees and cattle, and that such breach of agreement would be punishable by confiscation of a portion of the lands of the perpetrator of the crime by the local temple.[69]

Another method of prevention of damage was to make it obligatory on the part of persons to take prior permission from the local authorities to dig out earth from the tanks, so that proper control could be exercised over the persons in charge of such works. We also learn that the sluice gates, which formed an integral part of the irrigation works, were protected with utmost care. There were special settlements for guarding the sluice gates at night from any possible wanton damage by miscreants and unscrupulous elements.[70]

Remuneration for Maintenance

In south India, during the period under review, there was a practice in force to reward private individuals and public servants who voluntarily undertook the maintenance and restoration of irrigation works. The rewards were known as *érippaṭṭi* or *daśavandha* (*daśabandham*) grants. The term *ērippaṭṭi* (tank-land) did not specify any fixed wages, but merely referred to a gift or grant of land of varying sizes. However, in all the cases the granted land was free from all the dues and taxes. In a few cases, the grant carried with it certain stipulations. From the records we glean numerous instances of this type of grant which was in vogue in those days.

The other term, *daśavandha* or *daśavandham*, stood for grant of land as remuneration for the free services rendered by individuals to irrigation works.[71] Normally, a part of the land common to the village or a share of the produce was particularly earmarked for the purpose. We also learn from Kanarese records that the *daśavandha* grants were further supplemented by grants like *koḍange* or *koḍage, kaṭṭu-koḍage* and *biṭṭu-vaṭṭa*. The term has been correctly defined by L. Rice to mean 'the land granted to a person for repairing or building a tank on condition of paying in money or kind one tenth or some small share of the produce' or 'land granted at one-tenth of the usual rates to a person in consideration of his constructing or repairing a tank'.[72]

In AD 1541, when the residents of Tirumadihalli (Karnataka) repaired the breaches in the tank at their village, the government granted them one *khaṇḍuga* of *kaṭṭu-koḍage*.[73] Similarly, in 1636, when one Mekalabomma of a particular village in the district Kolar repaired the breaches in the tank in his village, he was granted one-fourth part of the wet lands near the breaches as a *daśavandha*.[74] A record[75] from the Cuddapah district stated that 'Hazarat Durbunḍage Dēvanalavaru' granted in s 1669 (1747) three *kuntās* of *daśavantham* for yearly repair of the tank to the Reḍḍis, Kāpus, Kammās and other farmers of the place.

In all the above examples we notice that the *daśavandha* grants were given as an allowance of land for the maintenance of irrigation works. In certain cases the Voḍḍars (tank-diggers) were directly given such grants in district Nellore of Andhra Pradesh. Baden-Powell, who had examined this term, defined *daśavandham* to be one among the *Ināms* for the construction, maintenance and repair of irrigation works in the Ceded Districts, in Krishna, Nellore, North Arcot and Salem, These *daśabandham Ināms* were granted as a recompense to private individuals, who constructed tanks, wells, and river channels, by means of which the revenue of the State was augmented. The extent and the value of the *Inām* were in proportion to the capital expended on the work and the out-turn in revenue'.[76]

The term *daśabandha*, having transformed in its intrinsic meaning through the ages, has now been confined to some parts of Andhra Pradsesh in connection with the administration of land. It would be of interest to add here that *daśavandham* was a subject of enquiry by the *Inām Commission* appointed in 1858-59 in the Madras Presidency during the British rule. It was one of the nine kinds of *Ināms* which were examined in depth as the validating titles.[77]

However, in spite of overwhelming inscriptional evidence describing the traditional arrangements for the management and maintenance of irrigation works, misleading notions still seem to persist. In this context, it is, therefore, difficult to accept W.H. Moreland's statement about southern India in the first half of the sixteenth century, that we do not find 'any suggestion of arrangements for keeping existing works in proper repair'.[78]

V. DISTRIBUTION OF IRRIGATION WATER

Distribution of water for irrigation was as difficult a problem in those days, as it is today. The rulers therefore framed certain specific rules and imposed certain restrictions taking into account all aspects of the proportion and supply of water. These rules and restrictions were in force since the days of the Pallavas. But there were certain exceptions in the implementation of these rules, for instance in the case of *dēvadāna* (temple) lands and *brahmadēva* (brahmin) villages. A typical example would give a fair idea of the rights and conditions attached to *dēvadāna* and *brahmadēya* grants in south India. We find in the copper-plate[79] grant of the Chōla Rājendra-I (sixth year) the following privileges and conditions for the use of water:

> The lands of this village shall be irrigated by canals dug (proportionally) as per water assigned (from these canals); others (who are not tenants of the *dêvadāna* lands) shall not be permitted to cuṭ branches from the canals (*kuṛanngaṛu*), dam (the passage of water) across, put up small piccotahs, or bale (out) water in baskets. The water thus assigned shall not be wasted. Such water shall be (appropriately) used for irrigation (after) being regulated. Channels and springs passing across the lands of other villages to irrigate (the lands of) the village shall be permitted to flow over the boundary line and cast up (silt); channels and springs passing across the lands of this village irrigate (the lands of) outside villages, shall also be permitted to flow over and cast up (silt).

Such *Vyavasthas* (declarations regarding the grants) were faithfully followed and implemented by the local assemblies in the case of the *dēvadāna* lands and *brahmadēya* villages. In non-*brahmadēya* villages the assembly of the *Ūr* decided the flow of water according to the area of the wet or dry land. In the *Nāḍu* assembly divisions it was the *nāṭṭar* who were in charge of water management besides discharging other important functions. In the Deccan, the *Mahājanas* under the supervision of the headman, *gaunḍa,* regulated the water supply, besides encouraging the construction and maintenance of irrigation works. In Andhra, the *āyagārs* were responsible for the distribution of water. In this task they were assisted by the water-man *(veṭṭi)*. The rural administrative bodies were thus able to control the water supply in the villages concerned.

Feuds and Disputes

Irrigation channels from tanks and rivers were excavated communally and served sometimes as demarcation lines between neighbouring fields and villages. It is learnt that water feuds and disputes did arise due to illegal turn-off of water supply to a particular field or village. Further, the water feuds and hostilities between adjacent villages or between hostile factions were often responsible for damage to irrigation works. In all cases the disagreements had to be brought before the local assembly to settle the differences between the uncompromising factions as satisfactorily as possible.

Individual disputes, which were civil in character, were normally amicably resolved by the residents of the village themselves;[80] otherwise the decision of the arbitrator was final and accepted, and the acceptance was confirmed in a few cases by a gift of land to the local temple. Sometimes disputes were attempted to be avoided by the residents themselves after purchasing the right of taking water for irrigation through a sluice gate of the tank for a specified sum of money; or by getting such rights as gift from the local assembly.

Feuds and hostilities between neighbouring villages in the distribution of water were also noticed in the lithic records. Here is a case wherein the higher authorities had to intervene when the local bodies failed to settle the dispute. In ad 1406 there arose a quarrel between two neighbouring villages with regard to the supply of water from the local tank. The dispute in question was finally amicably settled in the presence of *Mahāpradhāni Araśar* (Tipparāśar).[81] During the time of Narasimhayya Mahārāya an agreement was made between the residents of three neighbouring villages in the modern Chittor district regarding their respective rights to irrigate water from the channel called Sadāśivakōna.[82] Similarly, a record (AD 1426) issued in the reign of Mahāmandalēśvara Vīradēvarāya conveyed the final agreement entered into by the residents of the *vaḍa-Nemili* (Tamil Nadu) with those of six other villages about certain regulations of water supply from the river for irrigation of their lands.[83]

The ruling king had to intervene in certain disputes when the local authorities failed to settle them. This was resorted to as a final means of settling the disagreements among the aggrieved parties concerned. The following two clauses mentioned in the larger leiden-plates[84] of the Chōḷa Rājarāja-I tells us of the peaceful methods adopted by the state to secure peace and harmony among the people of the adjacent villages and to safeguard their rights:

> (1) The irrigation channels passing through the lands of this village to other villages in the outskirts shall be permitted to flow without any impediment of the donee; (2) the channels passing through outside villages to irrigate the lands of this village shall be allowed to flow uninterrupted by the people of the outlying villages.

The king also reserved the right to allow water to fields of temples and small and big land owners. A record[85] from Pudukkōṭṭai (Tamil Nadu) mentions the settlement of a dispute by the ruling king between the authorities of a temple and an individual regarding the ownership of a stream. It was decided by providing that, 'after irrigating certain specified field, one half of the income from fishing in the river should be made over to the temple authorities, while the other half was to be retained by the other party to the dispute'. Such instances, however, were only exceptions to the general statement that disputes and disaggreements were locally settled.

Ratio of Distribution

Private lands: The quantity of water to private lands was given according to the area of land under cultivation. The water rights attached to particular plots of land were often enumerated in the deed when they changed hands by sale or transfer. Sometimes the right of taking water for irrigation from a particular tank was sold to individuals for a specified sum of money.[86] Indeed some times the right of utilizing water partly for irrigation was even auctioned to the public. In AD 1225 the residents of a place sold 12 *mā* of land with trees, wells and tanks in a public auction to a dancing girl of a local temple for 14,000 current, genuine new coins. The vendor was entitled to take water to her land from the village tank for 16 *nāḷigai* (6 hours 24 minutes) every day.[87]

It is interesting to note in some inscriptions that the villagers and the temple shared the water in the ratio of their cultivable lands. When more than one agency was involved in the construction or repair of an irrigation work, it was generally accepted as a common rule that the water from the source would be shared in proportion to the expenses incurred by the parties concerned.[88]

Temple lands: As far as the temple lands were concerned there was unanimous agreement by all sections of society. The village assemblies held the same view. The ruling king often exercised his discretion in favour of temples; and the royal members always evinced keen interest in the irrigation of *dēvadāna* lands. And the contribution of private individuals in this direction was generous and sustaining. In certain cases the villagers themselves purchased the whole quantity of water and temple-area and endowed them for the exclusive benefit of the presiding deity of their village. This was mainly due to the religious sentiments of the people.[89] Under special circumstannces, they not only donated the tank to the temple but also promised to provide lands in proportion to the irrigating capacity of the reservoir.[90]

The medieval temples received considerable attention from the residents and devotees for regular supply of water for the sacred bath *(Tirumañjanam)* of the presiding deity. There are numerous references to this aspect of water supply in the lithic records.

Special privileges of temples: Apart from enjoying certain distinct privileges in the economic sphere—tolls, dues, taxes, property, etc.— the temples also enjoyed a unique and exclusive privilege in the matter of water supply. This privilege enjoined that the temple lands receive the 'first turn' of the water of the channel from the tank. And the local people in cooperation with the local governing body voluntarily provided the facility of diverting and allowing the 'first furn' of water to irrigate the temple lands.[91] This practice was prevalent in the Tamil speaking areas; but in the absence of evidence we are not sure of the prevalence of this practice in other areas.

Perhaps, this system of letting water to temple lands was established as a customary right. Sometimes the temple maintained the right to the flow of excess water to its lands and in certain cases this demand was readily granted by the *Ūr* assembly .[92] In addition to the privileged share in the flow of water, the temple exercised its right of drawing a certain portion —1/4th of the water flowing in the river or channel during times of scarcity, for a definite period, and the right was ungrudgingly granted by the local residents.[93] The temple could also prohibit others from using a particular tank reserved for it; the sanction to enforce this right was often the threat of calling down divine anger, and excommunication from the religious group.[94]

VI. ADMINISTRATION

Let us now review briefly the activities of the village assemblies in the sphere of irrigation and water supply. The inscriptions of the period indicate that the system of administration practised in south India was highly organized and efficient. Among the most important institutions of local government in south Indian history, three organizations— the *Śabhā,* the *Ūr,* and the *Nāḍus* —might be mentioned as the outstanding ones.

Role of Village Assemblies

Of the three assemblies, the *Śabhā* was found concentrated in four *Maṇḍalams* (regions)— the Toṇḍaimaṇḍalam, the Chōḷa-maṇḍalam, the Pāṇḍyamaṇḍalam, and the Koṇgumaṇḍalam. The *Śabhās* seem to have flourished in fertile regions between the rivers and on the banks of jungle streams. The famous Uttiramērūr inscriptions[95] (district Chingleput) belonging to the tenth century furnish full details about the constitution of the *Śabhā* assemblies and the mode of selection of members to them. The *Śabhā* consisted of several committees called the *Vāriyams,* of which the Tank Supervision Committee (*ēri-vāriyam*) was one. This committee consisted of six members who held office for 360 days and then retired. If any member was found guilty of an offence, he was removed at once. The functions and powers of the Tank Supervision Committee were quite obvious from the name; but the amplitude of these functions were not fully borne out from the inscriptions. It might be presumed that all endowments made in favour of tanks were entrusted to this committee, which undertook to invest the money endowments in the best possible manner and according to the rate specified by the donor. In a sense, the members acted as trustees for such endowments, and with the interest therefrom, the expenses incurred in dredging the tanks were met. In certain instances the Tank Supervision Committee was empowered by the village assembly to collect a regular tank cess *(ēri-āyam).* Besides, the committee also levied special imposts for construction of tank bunds. This committee also stimulated the flow of public charity for the general benefit of the community.

Almost to the end of the Chōḷa hegemony in south India, the composition of the *Śabhā* and this committee in matters of irrigation apparently continued to remain the same as at the beginning.

The second type of local assembly was the *Ūr,* which literally means a 'village' or 'town'. Of the exact composition of this assembly we have no direct knowledge. It was found working in non-*brahmadēya* villages independently and in several places alongside the *Śabhā.* All the residents of the *Ūr* were land owners. It was likely that this assembly carried on the same type of business as the *Śabhās* in the *brahmadēya* villages.

The *Nāḍu* was another type of assembly which existed in the territorial division known by the name ending with the suffix 'nadu'. Each *Nāḍu* had its sheriff and subordinate sheriffs. Records indicate that the *Nāḍu* assembly looked after the whole territory in matters of gifts of land, endowments, collection of revenue, distribution of land, water supply, and so on.

In the Deccan and in Karnataka the *Mahajānas* of the villages were in charge of the local administration under the leadership of the headmen, the *gaunḍas.* The activitives of the *Mahājanas* in respect of irrigation were similar to those of the local assemblies in the Tamil country. The *Mahājanas* under the supervision of the *gaunḍas,* regulated the water supply besides encouraging the construction and maintenance of irrigation works.

During the days of the Chāḷukyas of Kalyāṇi, the government seemed to have been divided into 32 *karaṇas,* secretariats or departments. The department of waterworks, *vāri-griha-karaṇa,* was one among them. The duties of this department were apparent from its name and were directly under the control of the central secretariat.

The situation in Andhra Pradesh during the Kākatīyas was different. For administrative purposes, the whole oganization was divided into two classes, the *sthala* (group of villages) and the *nāḍu* (combination of several *sthalas*). The village affairs were managed by a body of 12 government and non-government officials (members) collectively called the *āyagārs.* The non-government members of the *āyagār* system were professionals. One of the members, *Veṭṭi* or waterman *(nīrukaṭṭu)* attended to the task of keeping a watch over the tank-bund and regulated the flow of water for the purpose of irrigation.

Towards Centralized Governance

Vijayanagar, which was founded in the early fourteenth century by Harihara-I, was organized partly on feudal and partly on military basis. He is said to have reclaimed and brought under the plough large areas in the ceeded districts. Following the Kākatīya administrative system, he organized the country into *sthalas* and *nāḍus.* During the period of successive rulers, to augment the state revenue to finance additional expenditure on expanded armies, new forest areas were cleared and brought under cultivation. Large irrigation projects were initiated and completed. Subsequently, the Vijayanagar rulers conducted land surveys and made land-tax collection more efficient. In a highly centralized feudal set-up the administration was carried on by the *Mahāmaṇḍalēśvaras* (governors) appointed by the emperor. Working under the control of the emperor from the time of Harihara-II, these governors were not expected to foster the local organizations. Therefore, various activities of the village assemblies in rural areas were gradually taken over by the *Mahamaṇḍalēśvaras, Pradānis, Dannāyaks, Bhaṇḍārṇdaras* and others.

With the introduction of the *nāyaṇkara* and *āyagār* systems in the provincial and rural areas, the rural institutions like the *Śabhā,* the *Ūr* and the *Nāḍu* in the Tamil—speaking areas lost their importance and started declining and disintegrating. These systems took effective control over the village assemblies and took over many of their powers, privileges and duties.[96] So, in the final analysis, as rightly pointed out by K.A. Nilakanta Sastri, 'The admirable system of autonomous rule that had been established under the Chōḷas, and that survived intact for several generations after them, now fell into neglect and all but disappeared in this period, thanks to the pressure of military needs on the emperors and the feudatory *nāyakas.* The militarization of the empire proved disastrous to some of its most valued civil institutions.'[97]

The records of the period after the decline and fall of the Vijayanagar rule in south India show that the traditional irrigation systems and their management fell into disuse and became totally neglected. With the passage of time, the bonds that kept the village communities intact loosened and large areas under tank irrigation began to be deserted by the cultivators, who were left with no resources to maintain the irrigation works nor could they pay the hefty taxes on irrigated lands.

The above account indicates that, thanks to the forsightedness of the Hindu kings, the menacing twin problems of seasonal droughts and consequent famine were checked and brought under control. The present irrigation system of south India owes much to the orthodox Hindu kings who encouraged and motivated the construction of great irrigation works. This sketch of our knowledge of irrigation in south India may be closed with the remarks of Vincent A. Smith. He said: 'It is refreshing to note that the early Mohammadan Sovereigns in the Deccan did not entirely neglect the irrigation works of Hindu times but maintained and extended them.'[98]

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Section Three

SOCIAL DEVELOPMENT

CHAPTER XIV

Urbanism in India

Narayani Gupta

I. INTRODUCTION

In the history of towns in Europe, for the centuries after the eleventh, we have continuous literary and archaeological information, as against the earlier periods for which the available information is quite fragmented.[1] Likewise, in India too it is only from the eleventh century that we have reasonably continuous information about towns, from a variety of sources, literary, archaeological and pictorial. There are points of similarity between European and Indian urbanization, as there are points of divergence. From the end of the eighteenth century, industrialism introduced a new element into urbanization, first in Britain and then in other countries. At about the same time, European political control over parts of India also introduced a new factor into urbanization here. These features are beyond the scope of the present study, which is restricted to the period from the eleventh to the eighteenth century.

Geography and Topography

Less than fifty years before the Norman conquerors of England compiled the Domesday Book (1086), a great scientist scholar, Al-Beruni, wrote the first gazetteer of India, the *Tahqiq ma Lil Hind* (1030). Eight centuries later, Francis Buchanan began publishing accounts of *his* travels in India (1803), which also were like detailed gazetteers. He would have recognized much of the topography in Al-Beruni, just as we would find much in Buchanan familiar. India is a land of reassuring continuity.

On the older linguistic and cultural geographies of India, these seven centuries superimposed new sacred, commercial and political geographies. In this period cartography became highly developed in west Asia and Europe, and maps of many parts of the world were prepared. At present, we do not know of *Indian* maps older than the seventeenth century. Far from implying lack of knowledge, it was perhaps *because* most Indians had a very clear sense of place that they did not *need* maps.

Arab geographers from the ninth to the eleventh century became increasingly accurate. A map of 1375 showed the kingdoms of Delhi and Kollam. In 1307 Marco Polo had an exaggerated notion of the proportion of 'India', and he moved Bengal into China. Al-Beruni's itineraries, radiating from Kannauj, which he called 'the middle of India', seem hazy about south-east India. European maps of India, in which the Portuguese were the pioneers, were thick with place-names, particularly for the western coast. These centuries were rich in travelogues, where the authors, triumphant at actually reaching the desired destinations, perhaps invested them with an exaggerated glamour.

To Abul Fazl, writing in the sixteenth century, 'Hindustan' had a unity which was the gift of geography, of its climate and landscape:

> Hindustan is enclosed on the east, west and south by the ocean, but Ceylon, Achin, the Moluccas, Malacca and a considerable number of islands are accounted within its extent. To the north is a lofty range of mountains, part of which stretches along the uttermost limits of Hindustan, and its other extremity passes into Turkestan and Persia. An intermediate region lies between this and the vast frontiers of China, inhabited by various races, such as Kashmir, Great and Little Tibet, Kishtawar and others. This quarter may therefore be likened to another ocean. With all its magnitude of extent and the mightiness of its empire it is unequalled in its climate, its rapid succession of harvests and the equable temperament of its people. Notwithstanding its vast size, it is cultivated throughout. You cannot accomplish a stage nor indeed travel a *kos* without meeting with populous and flourishing villages, nor without being gladdened by the sight of sweet waters, delightful verdure and enchanting downs. In the autumn and throughout the depth of winter the plains are green and the trees in foliage. During the rainy season which extends from the close of the sun's stay in Gemini to his entry into the sign of Virgo (middle of June to end of August), the elasticity of the atmosphere is enough to transport the most dispirited and lend the vigour of youth to old age. Shall I praise the refulgence of its skies or the marvellous fertility of its soil?

II. VARIETIES OF URBANISM IN INDIA

In these seven centuries, Buddhism had shrunk in importance and in the number of its adherents. The 'bhakti' strain of Hindu faiths had gained ground, and was celebrated in temple-building and pilgrimages. Islamic communities were established, initially in the west and south, and later along the Ganga valley all the way to Bengal. The volume of intra-India, overseas and overland trade increased. Power struggles altered boundaries and affected cultural patterns. Trade, cults, and empire-building were the three variables that affected the nature of towns, and their numbers.

How did the Indians themselves refer to or describe towns? Not in terms of ideology but of functions. To the Sanskrit words used to mean 'town'—*nagaram, pattanam, puram*—were now added some from west Asia—*shahar, ganj, qasba, bandar,* the last three with specifically economic connotations. Also *qalah, kot* and *garh* (the last in Hindi/Marathi) were added in the seventeenth century.

The establishment of states ruled by Muslims was to lead to historians creating stereotypes. Considerable confusion could be caused by using typologies for towns. The terms 'Hindu' and 'Islamic' overlooked many elements of commonality. There was also the use of such terms as 'Muslim north' and 'Hindu south'. But towns in Europe had not been typecast as 'Christian', even though they were fairly homogeneous (cf. Mumford, p. 316: ' May one speak of the medieval town as a Christian city ?'). The term 'the Islamic city' is an orientalist construct, which ignores the strong urban tradition of India, and its regional variations. The form, architecture, nomenclature and cultural expressions in Indian towns had many points of similarity with those of other countries. These were contributed by individuals of the west and central Asian diaspora, who made these open cities their home.

In these centuries western Europe was moving from the tentative urbanism of markets and cathedral-towns, through the renaissance of neo-Greek and neo-Roman styles to baroque towns. In India, the inducements to establish towns were numerous, by way of abundant natural resources and handicrafts. The resultant extensive urbanism was characterized by wealth—the wealth of temples, of rulers, of bankers and merchants. But this wealth was not matched with security. In Europe, the sanctity of private landed property was ensured from the sixteenth century not just by military deterrents but by regulation—old Testament ideology, Roman Law and the Christian distinction between secular and sacred, between public and private. By contrast, in India, wealth was translated into 'portable property' (*Great Expectations*); towns endured, but their wealth often took flight or was captured. The rapidity of town building and dismantling created a vivid impression that they were impermanent (cf. C. J. Baker, describing Indian towns as 'very unstable', p. 334 ff). Very often, certain sites were in use again, under different names.

Establishment of Trade Emporia

India has one of the longest coastlines of any subcontinent. It had a large number of ports, though all of them did not have good harbours. Trade between the Mediterranean and Asia had declined between the fifth and the ninth century; it picked up from the ninth to the eleventh century; and the oceanic trade (supplementing and later replacing the overland trade) grew in volume from the eleventh century. There were many entree-ports for merchants from China, south-east and south Asia to east Africa and west Asia, and thence to the Mediterranean. Each region's ports were linked to other Asian countries—Bengal and Orissa to China and south-east Asia, Gujarat to west Asia, and Kerala to China and west Asia. Many ports were points of exchange between the east Asians on the one hand and the Arabs and Europeans, on the other.

There were at least six major sections of the coast on the west: from Sind to Chaul, thence to Mangalore, and from Cannanore to Anjengo; on the east, from Bimli-pattanam to Masulipatam, Armagaon to Tuticorin, and from the Ganga delta to Saptagram. In these sections, over this long period, there were ports that 'rose' and 'fell' because of natural factors like silting (the classic example being Tamralipti) or political factors like the concentration of routes on a particular port. Each section of the coast usually had one major port. Whenever a large state was established, it was served by at least one such major port—for example, Goa for Bijapur, Pulicat for Vijayanagar, Cambay for Gujarat and Surat for Mughal Agra.

A *pattanam* (a port of exchange) was described in a Tamil classic as a place where people sang in the streets, where three kinds of Tamil were spoken, where all kinds of fruit and flowers grew, and where all religious observances were properly performed. Indian rulers and wealthy individuals encouraged the import of Arab horses, Sri Lankan elephants, east African ivory, Sumatran pepper, and Chinese porcelain, besides diamonds, gold and silver. The exports included textiles, indigo, sugar, rice, opium, metalware, spices and pepper. Some of the ports developed into craft centres, with the growth of inland markets, and encouraged by the introduction of skills from overseas (e.g. Chinese techniques of silk culture and weaving at Chaul—cf. Kulkarni in I. Banga, p. 109). It is possible that Arabs and Europeans invested capital to develop urban crafts, or to link the towns with specialist urban centres in the interior. Dhaka muslins, the printed cottons of Musulipatam, indigo from Bayana, the metalware of Sialkot and velvets of Ahmedabad, were all internationally known. Some ports, notably Surat, also had a busy ship-building industry. The attention paid to good roads from ports to inland towns in Akbar's empire boosted the volume of imports to the north, at the same time as the fall of Vijayanagar led to a sudden fall in the volume of imports to the lower Deccan.

Krishnadevaraya or Akbar did not have the shrewdness of Henry VII: since they realized so much wealth from land revenue alone, they did not exert themselves to appropriate any share of the wealth generated by foreign trade. Unlike the calculatedly xenophobic measures dictated by mercantilist principles, Krishnadevaraya believed that:

> A king should improve the harbours of his country and so encourage its commerce that horses, elephants, precious gems, sandalwood, pearls and other articles are freely imported. He should arrange that the foreign sailors who land in his country on account of storms, illness and exhaustion are looked after in a manner suitable to their nationalities. Make the merchants of distant foreign countries who import elephants and good horses be attached to yourself by providing them with daily audience, presents and allowing decent profits. Then those articles will never go to your enemies (Stein, *Vijayanagara,* p. 52).

Lack of Mercantilist Spirit

Foreign merchants were fortunate in enjoying generosity and sometimes even hospitality from the local rulers. The administrative organization for mercantile transactions was very sophisticated, and the foreign merchants, under the *Shahbandar,* could get added advantage by lending their military and engineering skills to local rulers when the ports were threatened by supra-local authorities like the Mughals and the Marathas. The Indian merchants, too, had their interests intermeshed with those of foreign merchants, and did not always feel bound to make common cause with the rulers. With the *qanungo* as their spokesman (Das Gupta, p.27) they were fairly autonomous, though they never became strong oligarchies with political power, as happened in this period in the port-cities of Italy and the Baltic, and later in the Netherlands and Britain. The *mahajans, sahukars* and *jama'ts* never coalesced into professional classes. The occasional powerful *nagarseth* of Surat or assertive *zamindar* of Calicut (Das Gupta, p. 87, and Das Gupta & Pearson, p.166) were not the equivalents of European merchants.

Those involved in trade had highly specialized functions. The networks of bankers which stretched from ports to inland towns (cf. L. Subramaniam in I. Banga), merchants dealing with specific commodities, shipbuilders, seafarers, were all distinct subgroups.

From the time of the Brahminical revival in the eleventh century, the taboo on venturing on the seas as applied to the higher *varnas* checked practices like Brahmin priests going abroad to west and south-east Asia. It also engendered a curious inverted snobbery about the undesirableness of going out to sea, which made it easier for non-Indian merchants to control the growing overseas trade.

Another instance of a group that did not grasp what it could mean to become a 'sea-power' was that of the Mughals. In 1573 when Akbar conquered Gujarat, the men of the mountains looked out on the ocean. The Buland Darwaza of Agra faced Surat, and thence Mecca; therefore Surat was called *Bandar Mubarak.* It became the port of embarkation for the *hajj,* tempting even Akbar to undertake the journey,as his mother had earlier done. Large state-owned ships sailed from Surat to Jeddah each season, with thousands of pilgrims and a great deal of goods on board (Das Gupta and Pearson, p. 18). This could have been a good opportunity for Surat to control the seas, but Akbar 'tacitly acquiesced in the Portuguese supremacy, and (took) licences from them for the ships he sent to the Red Sea' (S.M. Ikram, p. 219).

The Portuguese had already taken advantages of the fall of Vijayanagar to strengthen their own position in the ports of Honavar, Mangalore and Goa. At the same time, their treaty with Calicut, and the monopoly they created for Goa led to the decline of trade in Cochin and Cannanore. This was the writing on the wall which the Indian merchants in other ports failed to read. The result was the collapse of many other ports in the eighteenth century, as the three British ports grew in strength.

Development of Port Cities

The ports were cosmopolitan, and of necessity, were models of tolerance in their social relations and political attitudes. The merchants enjoyed political protection, locally and regionally. The merchants' settlements in the towns were quite distinct (even today clearly visible in Cochin, where the Jews, local Christians, Portuguese, Konkanis and Muslims each was a separate street). There were in most towns magnificent mosques built and patronized by foreign merchants. The governor's palace was adjacent to the inner city *(shahar-panāh)*, as in the case of inland towns; beyond these would be the outer suburbs *(ālam panāh)*, often also walled. The defences were against the inland empires, not foreign forces, until the intra-European rivalries of the eighteenth century changed the picture. The first major violation of the policy of coexistence was perpetuated by the Portuguese; there are accounts of their soldiers staggering under the weight of the booty they captured when Calicut was thrown open for plunder (Boxer, p. 300).

III. EMERGENCE OF CULT CENTRES

These centuries saw two parallel developments on an all-India scale, one independent of and the other connected with, political changes. The first was the elaboration of Hindu pilgrimage on a regional and a pan-Indian basis. Like the *hajj*, this practice brought people together and also helped commercial exchange. The second was the construction of substantial Hindu and Muslim places of worship. Like the contemporary spurt of cathedral buiding in western Europe, this also had major generative functions. 'Religion and commerce are sister-arts in India', an Englishman was to comment in the eighteenth century.

From the tenth century onward there was a quantum increase in the output of monumental architecture. Massive temples were built in stone—thus generating mass-empoyment and serving as a form of insurance for the rulers. It is significant that in Tamil the word 'kovil' signifies both the king's palace and the temple. Temple deities, with their homes, wealth and landed property, became more constant generators of urbanism than the secular rulers.

Temple-towns and Political Power

The later Chola temples (1170-1250) were 'landholder, employer, consumer of goods and services, bank, school and museum, hospital and theatre'. From the thirteenth century, the landscape of Tamilnadu was dotted with sacred *('thiru')* towns generated by the *bhakti* cults. Over 2000 temples were built in the Tamil area alone between 1300 and 1750 (Raychaudhuri I.113). Another area which saw a similar spurt in temple-building, from the twelfth century onward, was Orissa. Here great stone temples were built in the *brahma-deyas*, which were located near the many small kingdoms. A self-confident Hinduist movement designated the cities of Shiva (at Bhuvaneswar) and of Vishnu/Krishna (at Purushottam Puri, later abbreviated to Puri). The Jagannath temple was constructed at the same time as the Qutb Minar was being raised at Delhi, also as a statement of power. Puri was, like Delhi, strategically well-located, at the crossroads of trade between eastern India, Burma and China. This was part of the move to create overarching large kingdoms, strengthened by linking royal authority with the brahminical temples, which absorbed local cults into their rituals. Rulers, brahmans, and individual or corporate donors at these major shrines were knit together in a complex and highly practical web of protection, recognition, and contribution to public works (in the temple lands). The employment generated by the temples made many of them develop into urban sites. This happened particularly dramatically in Orissa, where trade and manufacture had been less market-oriented than in the south (Kulke, p. 3 ff). The building of temples attracted highly-skilled artisans. Later, the temples became centres of dance and music and Sanskrit scholarship.

The strength that rulers derived from their patronage of the Jagannath temple was such that, much later, in the eighteenth and nineteenth centuries, other Orissa rajas were to follow the practice (Kulke, p. 80). Similarly, in the eighteenth century, the chieftains who were the ultimate successors to the Vijayanagara empire, the *palaiyakars* of Tanjore, Pudukottai, Tondaiman and Ramnad built temples and encouraged brahmins to settle in their towns. They also claimed the right to protect temples, for the very practical reason that most of these had been fortified and were thus strategically useful; also, the control gave them the right to tax the pilgrim revenues of the temples (S. Bayly, pp. 56-8).

The temples of Somnath, Multan, Madurai and Srirangam, with the accumulation of wealth given in offerings as insurance or thanksgiving by rich merchants and successful rulers, were a standing temptation to gold-starved rulers like Harshavardhana or Mahmud Ghaznavi (Kosambi, p. 366). 'When Muhammad Ibn Al Kasim conquered Multan', wrote Al-Beruni, 'he enquired how the town had become so very flourishing and so many treasures had been there accumulated, and then he found out that this idol was the cause, for there came pilgrims from all sides to visit it' (Al-Beruni, I. 116). After Mohammad Qasim looted the temple, the pilgrims forsook the city (*ibid.*), while the immobilized wealth of the temple found its way back into the economy (Wink, pp. 301-2).

Manufacture of Sacred Geography

Pilgrimage was specifically part of the Buddhist canon. The dying Buddha had prescribed four places of pilgrimage—the sites of his birth, his attainment of Enlightenment, his proclamation of Truth, and his Passage from the world. The Quran required every Muslim to make a pilgrimage to Mecca and Medina. Pauranic Hinduism also urged pilgrimage to *tirthas*—whether this followed on or was coeval with the *mahayana* exhortations is not clear. Abul Fazl wrote, 'The physicians of the spiritual order...have bestowed on certain places a reputation for sanctity...and the toils of the pilgrimage (are) a means of facilitating the attainment of the aim (of seeking God)' (*Ain-e-Akbari,* III, p. 332). Abul Fazl listed the shrines on the sacred rivers and the cities 'dedicated to the divinities': Kasi, 'on the *Shivratri,* multitudes resort thither from distant places and it is considered one of the most chosen places in which to die' (*ibid,* p. 334), Ayodhya, Ujjain, Avantika, Kanchi, Mathura, Hardwar, Dwarka, Prayag and Nagarkot. He also listed many secondary shrines as well (*Ain-e-Akbari,* III, pp. 332-6).

Nagarjunakonda was a major Buddhist shrine. The *bhakti* cult gave rise to many new shrines—like the thirteenth century temple of Pandharpur, a centre of sanctity for Vaishnavs. For a few days every year, this small town on the edge of the Marathi-speaking area became transformed into the sacred place of Pundalik, a *bhakta* of Vithoba. 'The word "Pandharpur" has come to represent...not the *God* Vithoba but the town, temple and *idea* of Pandharpur, the centre of the stream of pilgrims' (E. Zelliot, p. 35). A seventeenth century pilgrimage by Jains from Agra to Ahichhatra and Koil is described by Banarasi (Banarasi, pp. 83-5). Political upheavals did not deter people making such journeys. In the eighteenth century the raja of Pudukottai, in the heart of a war-ravaged region, though it fit to go on a pilgrimage to Kashi (S.Bayly, p. 57).

A sacred geography was also being manufactured by the Puranas, and by a man called Vidyaranya. Founder of the *matha* in Sringeri and patron of the kingdom of Vijayanagar in the 1330s, he wrote the *Sankara-digvijaya* (1330s) in which he claimed that the philosopher Śaṅkarāchārya had 'conquered' the four directions by founding shrines at four cardinal points—Badari, Puri, Sringeri and Dwarka. There is no evidence of Śaṅkarāchārya having even gone to Puri (R.L. Mitra, xvii), and the choice of Sringeri was a marker in that town's running battle for precedence with the older town of Kanchi, an aspect of Kanada-Tamil rivalry in the wake of the establishment of Vijayanagar's sovereignty (Kulke, p. 236). Vaishnava sacred geography was mapped out in Chaitanaya's journey in the sixteenth century, with Baijwada, Cuddapah, Arcot, Kanchi, Chidambaram, Kumbakonam, Srirangam, Madurai, Rameshwaram, Sringeri, Udipi, Kolhapur, Pandharpur forming a comprehensive circuit of south India.

Older rituals like the Kumbh Mela meant that Prayag and Hardwar had to play host at fixed times to thousands of pilgrims paying homage to the country's national geography. The course of the Ganga, irrespective of whose territory it flowed through, had an autonomous sanctity, shared by other rivers.

The *rathyatras*, to which there are references from the ninth century, became formalized in the thirteenth century (H.S. Patnaik). Using the 'mobile architecture' of the elaborate temple-shaped *rathas* (like the *tazias* in later Mohurram ceremonial), they briefly created a community out of the many discrete worshippers. 'They extend(ed) the ritual and sacred sphere of the temple into major parts of the town, thus transforming Puri (= 'town') into a veritable temple city' (Kulke, p. 71). Later Patrick Geddes was to write: 'In my town-planning discourses I cannot but defend this ceremonial of the car, as a civic institution...To this we owe the fine layout of the main quadrangle of streets of a Temple City.' Other ritual movements in other towns—the processions for Ram Leela and Mohurram—also knit the people together, though they did not *shape* the town, except at Varanasi (A. Kapur).

Puri also derived its popularity from many individuals—Jayadeva in the twelfth century (Lee Siegel) and Chaitanya in the sixteenth. After Chaitanya migrated there in 1510, the annual visit to Puri for a stay of a few months by his followers from Bengal became a regular feature. M.T. Kennedy noted:

> The vociferous entrance (of the Bengal pilgrims) into the city was watched by the King Prataparudra from the roof of his palace. The chanting of Bengali songs by 200 lusty throats...filled the king with amazement (quoted in Kennedy, p. 43).

The association with the Chaitanya cult gave the Puri shrine added publicity. The hero of Muhammad Jaisi's *Padmavati* (sixteenth century) worshipped at the Jagannath temple. In the seventeenth century Osman of Ghazipur described the shipwrecked Sujan Rai of Nepal coming to 'the city of Jagannath, the light of the whole world' (Patnaik, p. 94). Puri was a major shrine not only for Hindus of eastern India, it was also a *pied-à-terre* for Buddhist pilgrims from the neighbouring countries in the north and the east, whence they came to India to do the Buddhist circuit (Das Gupta and Pearson, p. 17).

Pilgrimage as a Source of Revenue

'Political' towns might decline, as also the secular control of a town; but the town as a shrine was a permanent landmark. And as Puri became increasingly well-known, it became a major source of the pilgrim-tax (Cassels). This term overlapped with a number of monetary contributions extorted from pilgrims according to their economic status, by officials, priests and landholders on the pilgrim route.

Gaya and Prayag were the other major towns where this tax was extorted. The arguments for and against the tax were reminiscent of the battle over the pilgrim-tax on *hajjis* levied in Syria, removed by Salah-al-din and reimposed later, though Muslim jurists had pronounced it illegal (F.E. Peters, p.109). This temptation to make capital out of popular shrines was not specific to Muslims. In the Tamil region in the seventeenth and eighteenth centuries. 'through his patronage the chief might establish a right to tax the temple's pilgrim revenue' (S.Bayly, p. 56).

When Puri became a pawn in the sixteenth century struggle between the Bengal Afghans, the Mughals and the Sultan of Golconda, the idols were frequently smuggled away to safety. Over a century later, a *subahdar* was staggered when he worked out that the idols' absence cost the imperial treasury nine lakhs in pilgrim-tax. He re-established the idols (1735) and the flood of pilgrims—and revenue—began to flow again (*Rias* p.302 ff). There were other instances when Muslim administrators protected Hindu *tirthas* because they were a source of income. Nadia (reincarnated as Nabadwip), which declined as an administrative centre, got a new lease of life in the sixteenth century because of its association with Chaitanya (Kennedy, Morinis). The populist Vaishnava cult generated a mass-consciousnss that changed the character of this pandit-dominated town. The Brahmins appealed to the Muslim governor to end the irritation caused by the Vaishnavas' chanting, with bizarre consequences.

> When (the *Sankirtan*) was transferred from Srivasa's county and to the streets of the city, an appeal was made to the Muslim governor to suppress it as a public nuisance. He issued some sort of order against the Vaishnavas. In answer to this, Chaitanya organized a monster *nagarkirtan* and, dividing his forces into 14 groups, paraded through the city, finally massing his singers before the Governor's residence. There the emotional influence emanating from the singing and dancing of hundreds of men proved too much for the Muslim magistrate. He was constrained to recognize the spiritual nature of the Vaishnava activities and, it is alleged, even joined the *Sankirtan* himself ! (Kennedy, 27).

From the sixteenth century, Nabadwip has remained, with its 750 *mathas*, a major pilgrim destination for the Bengali culture-area.

Mathura was on the pilgrim's itinerary. It was Chaitanya's instructions to his disciples that led to the twin town of Brindavan, the place associated with Krishna's youth, emerging from thick woodlands to become another pilgrim-destination, with the forgotten sites of the Krishna-cult relabelled. The four major temples at Brindavan (notably the Govindaraja) were built in 1590 to commemorate a visit by Emperor Akbar, who came to Brindavan 'drawn by the fame of the Goswamis' (Kennedy, p.67)—a rare instance of 'instant architecture' to celebrate a political event.

Sanctity with Religious Tolerance

In many 'sacred' towns, Hindu, Buddhist and Jain traditions and cult-places overlapped, as also did the Hindu and Islamic. The 'Hindu' city of Varanasi had at least 30 major Muslim *mazars*, apart from those of only local interest (Freitag, p. 164). It was a city that welcomed visitors. In the twelfth century, the Iranian poet Sheikh Ali Hazeen wrote that he did not wish to leave this city, where every scholar was treated with the deference due to Ram and Lakshman:

> *Az Banaras na ravam, mabadi-am ast een ja har Brahman-pisarey Lachman-o-Ram ast een ja.*
> (The people of Banaras admired and respected me and my talents in like manner, and that is what I longed for during all these wanderings from Ispahan, my native place, to Banaras. Hence I feel satisfied to remain here till I die.)

When he died in 1180, Sheikh Ali Hazeen was buried in Banaras (B.N. Saraswati, S.C. Malik and Madhu Khanna, p.26).

Sanctity gave permanence to many urban places. They also gave them a quality of openness where money mattered more than caste (Cassels). In some places Sufi/syncretic traditions dovetailed with a *bhakti* one, as at Varanasi. Sufi saints gave a permanence to sites which might otherwise have not lasted long. Their chief shrine was at Ajmer, where

Muinuddin of Khurasan died in 1236, converting the provincial capital which had just been conquerred by Altmash into a permanent sacred city. Akbar walked all the way from Agra to Ajmer in 1570, taking 16 days at the rate of 14 miles a day (*Akbarnama*, II, pp. 510-11). Ajmer Sharif became the local substitute for Medina, and the mingling of traditions there would explain why the officials at Medina were surprised when Indian pilgrims prostrated themselves in a manner obviously learned from Hindu devotees (F.E.Peters, 258). Other Chishti shrines were at Srinagar, Gujrat (Punjab), Lahore, Multan, Uch, Pakpattan, Sirhind ('the summit of Hind', founded in the twelfth century), Badayun, Bahraich, Nagaur, Jaunpur, Pandua and Gaur.

A major centre was Delhi ; Bakhtiyar Kaki (d.1237) must have located his *khanqah* in Mehrauli because it was near the capital of the Sultanate, but as a result the Chisti *silsilah* acquired a permanent base in Delhi. Delhi had a staccato political importance but *Hazrat* Dilli, particularly the shrines of Nizamuddin Auliya (d.1324), Bakhtiyar Kaki and Roshan Chiragh Dilli, drew in pilgrims, and made it a favoured site for mausolea and a halting place on the *ziyarat* of the Mughals (*Akbarnama*, II, p. 511) which eventually led to Humayun and Shahjahan again choosing it for their capital.

When the Bahmani kingdom broke away from the Delhi Sultanate, Sufi shrines were established in the towns of Gulbarga and Bijapur. Gesudaraz (1321-1422) began the tradition of Sufis migrating from Delhi to Gulbarga. In nearby Bidar, many Sufis arrived directly from the Arab states, especially from Baghdad, after that city fell to the Mongols in 1358. When Bidar lost its political importance and that of Bijapur rose, many of these Sufis moved; by contrast to the Delhi Sufis, who were near the city but not of it, these were characterized by their 'urbanism' (Eaton, p. 55). Later, the city offered refuge to the Sufis expelled by Shah Abbas I of Iran (1588-1627). There is the story of Shah Fathullah of Shiraz, a sage and intellectual, who was invited to Bijapur by the ruler. From there Akbar took him to Fatehpur Sikri where he became Minister in charge of religious affairs (Ikram, p.153). Many decades later, when Aurangzeb destroyed the great city of Bijapur, the dead city was found to have as many as 200 Sufi *dargahs* within the city walls and 200 outside. The Sufis themselves fled the devastated city (Eaton, xxiv). After Aurangzeb's death, another wave of refugees came to Indian towns from Iran, where the Afghan invasion of 1722 had led to the Shias of Isfahan fleeing to India (Hamid Algar, p.30).

The young tradition of Sikhism had also its shrines, associated with the gurus—Khadoor Sahib, Tarn Taran, Goindwal, Nankana Sahib, Amritsar (established in the 1580s on a jagir granted by Akbar) and Sri Hargobindpur (Gurdaspur). The last named town was remarkable in having been laid out according to the directions of Guru Hargobind, with a high wall, efficient drainage, *pucca* streets and good lighting (*Sunday Statesman*, 10 April 1994).

The one exception to the open city tradition was Goa, which embodied a policy of religious intolerance. A port of antiquity, it was conquered by the Portuguese in 1510, after which it became an outpost of militant Catholicism, particularly after the Council of Trent in 1567. Education was controlled by priests, the Inquisition established itself in a great palace, Hindu and Muslim shrines were destroyed, and pilgrims were not allowed passage through the city-state. This 'Lisbon of the East' was a matter of great pride for the Portuguese. After seeing the Viceroy's court, they declared, they did not need to visit Lisbon. Its gleaming white churches, convents and houses were built by local *gaunder* masons with strict orders that no Indians were to paint *their* houses white (Pearson, pp. 89-130). Goa was a source of greater pride the the vast colony of Brazil, and claimed to control '29 cities and 33 states' (Boxer, p 69).

It has populous towns
By big villages surrounded,
Strong, magnificent of stone,

Lime brightly shining
Houses of a thousand perfections.
Garcia de Resendre, *Miscellanea,* 1533 (quoted by F. Castelo Branco, 1989)

Abandoned because of disease, old Goa remained preserved in amber, its cruelties and intolerance forgotten. Only the beauty of its buildings remained to captivate the eye, just as with the Aztecs whose civilization the Iberians had so wilfully destroyed. By 1760 old Goa was destroyed and served as a quarry for the new town (Rose Macaulay, p. 259). Its ruins did not 'get swallowed up in the earth' as many Portuguese feared; instead, they were to be identified as a World Heritage Site in 1987.

IV. URBAN NETWORKS

In this period there were four empires, and in the eighteenth century there were to be other attempts at empire-building. Empires necessitated lines and means of communication, and in turn revenue collection centres and halting places—*sarais* and *qasbas.* On the frontiers, fortified areas were needed. Above all, they needed capital cities which conveyed the image of power and grandeur. The bigger towns and cities became major centres of consumption, with heavy concentrations of craftsmen, artisans, merchants, bankers, soldiers and service personnel. At the same time, the establishment of large empires reduced the autonomy of merchant-assemblies, as in the *nagarams* and *erivirapattanams* in south India.

To sustain these settlements, flourishing agriculture, water-supply networks and good roads were needed. From the tenth century there occurred the great stone revolution in India, which produced not only many temples but also palaces, bridges and embankments. The absence of stone was a disadvantage. Bengal had the advantages of the biggest delta in the world and of rich agriculture but, lacking stone, the rivers could not be embanked, and the heavy floods and rapid silting imperilled the towns. Two centuries after the great public works in Sri Lanka, the Cholas in the south carved out tanks, canals and *anicuts,* to be followed by the roads and canals of the Khilijis and Tughlaqs in the north. A rich agriculture was generated by the *devadanas* and *brahmadayas* granted to temples and priests. Secure from fear of royal appropriation, these also became the nuclei of cult-towns. The forests of Andhra, Orissa and Awadh were cleared for cultivation and to build roads and establish small towns. There were examples of defunct settlements being revived (for Punjab, J.S. Grewal as quoted in J.F. Richards, p.194).

Road Building and New Settlements

Eastern India, from being a frontier zone beyond Darbhanga, looking to the countries further east to which it was linked by Buddhism and trade, became first a Hindu kingdom and then a *subah* of the Mughal empire. The forts built for defence against western invaders proved convenient for the Mughal officials who defended the *subah* against frontier tribes and the *Marathas.* Successive Mughal capitals along the Ganga—Gaur, Pandua, Tanda, Rajmahal and the major town of Burdwan—formed an important line of defence, and remained vigorous because of the Grand Trunk Road, linking the trade of south-east Asia to the Mughal empire (McLane, p. 123). From the 1540s, Patna, at the confluence of the Son and the Ganga, and Sirhind, Lahore and Multan became busy trade emporia. Another route from the sea to the interior was created after the Arab colonization of Sind in the ninth century (Cambay/Surat, Debal, Ar-rar, Mansura and Multan).

The conquest of Surat by the Mughals helped many small towns in Rajputana founded in the fifteenth century. From the ports on the western coast, excellent roads also led to the knot-towns in the Ghats—Ajmer, Ahmedabad, Pune, Deogiri, Coimbatore. 'The gap in the

Aravallies ensured that Ajmer must be a garrison town or a commercial market, even if the shrine of a saint was not there.' (Raychaudhuri I. p. 11.) In Akbar's reign, the network of Mughal roads was extended to the south, and caravans of thousands of oxen wended their way from Kochi to Bengal and central Asia. Ibn Batuta (fourteenth century) praised the Goa-Quilon highway (a 2-month march !) with a wooden shed and benches for weary travellers after every half-mile (Ibn Batuta, p. 231).

In the irregular landscape of the Deccan ghats, forts at strategic points were necessary, and these were built by the Adil Shahis of Bijapur in the sixteenth century (Fukazawa, p. 7), the Nayaks who succeeded Vijayanagar, and Tipu Sultan (eighteenth century). The suffix *palayam* (cantonment) and *palaiyakar* ('poligar') referred to the many independent chiefdoms of the sixteenth-eightenth century, which were above all military strongholds, but also attracted Chetti merchants and *bhakti* preachers. Most of them were enclosed by, or were near, major temples like those at Madurai, Rameswaram, Tanjore, Senji and Tiruchirapalli (S. Bayly, pp. 56-60).

The *nayaks* did not want to be stereotyped as 'Hindu' kings, and gave land-grants to Catholics and Muslims as well—as had been done by other rulers before and after them (Rao, Shulman, Subrahmanyam pp. 89-90). Thus the break-up of empires—Vijayanagara in the sixteenth, Mughal in the eighteenth—gave rise to a multiplicity of urban areas, sometimes simple military strongholds, but ultimately small replicas of the cosmopolitan urban cultures, on the ruins of which they were established.

New towns were quickly built, with buildings of mud-brick. And they equally quickly fell apart. When many buildings were in ruins, it seemed simpler to move to a new site. It was cheaper to build a new settlement than to repair and rebuild a deteriorated/ravaged one. 'In Hindustan,' exclaimed Babur,

> hamlets and villages, towns indeed, are depopulated and set up in a moment. If the people of a large town, one inhabited for years even, flee from it they do it in such a way that not a sign or trace of them remains in a day. On the other hand, if they fix their eyes on a place in which to settle, they need not dig water-courses or construct dams because their crops are all raingrown, and as the population of Hindustan is unlimited, it swarms in. They make a tank or dig a well. They need not build houses or set up walls. *Khas* grass abounds, wood is unlimited, huts are made, and straightaway there is a village or a town' (*Baburnama*, pp. 487-8).

The Great Cities

Babur might have had smaller settlements in mind, but even the more monumental cities were built with astonishing rapidity. The two cities of victory—Vijayanagar and Fatehpur—are classic examples. Islamic civilization was characterized by great cities, but they were by no means unknown to pre-Islamic India.

Around 1600, Delhi, Lahore and Agra, the great Mughal cities, had about 5,00,000 inhabitants each, when Tudor London had only 1,70,000 and Lisbon 1,10,000 inhabitants. The Mughal cities occupied an average area of 500 hectares. Vijayanagara was also a thickly populated town, but the inhabitants were scattered over a bigger area. In the Tamil tradition, towns were a status symbol. In the thirteenth century, in the after-glow of Chola greatness, a Tamil inscription referred to the *Madavidu padinettu pattanan*, which meant '18 towns with palatial buildings' (B. Stein, *Peasant State*, p. 251).

Indian cities then (as now) were a mixture of the monumental, the utilitarian and the informal. Of Ajmer, a later observer was to say that 'like all other towns of India, it exhibits poverty and ease in juxtaposition' (Tod, vol. 2, p. 895). There was a distinct lack of investment—economic and emotional—by the average town-dweller in any area of the town. This could be explained by the absence of inalienable rights in land or buildings.

By contrast, there was a great deal of interest—and very often good taste—in architecture and even in urban planning on the part of the rulers and nobles. In the Islamic tradition 'engineers and architects enjoyed high social prestige and the title *muhandis* was added to their name; *al-mimar* was also used for architects' (al Hassan, p. 265, Qaisar, pp. 6-15). India was the land of opportunity for talented engineers from Iraq, Iran and central Asia, particularly from the mid-thirteenth to fourteenth century, when these areas were ravaged by Mongol incursions. Again, the Persian connection during Mughal rule brought Persians like Ali Mardan to India (Ebba Koch, p. 96), where they were helped by innumerable skilled workers who were so easily available. In the south, 'skilled artisans comprising the *kammalar* achieved new prerogatives and social privileges during the late eleventh and twelfth centuries as their services in connection with temple-building appreciated' (Stein, *Peasant State,* p. 248). In 1398 Taimur took away scores of artisans from Delhi to join the workers recruited from Azerbaijan and Fars to build Samarkand. When Babur came to north India, he found the towns unattractive and said that the people of India had 'no skill—in design or architecture' (Elliott and Dowson, vol. 4, p. 222); yet, he was impressed by the easy availability of artisans. He said:

> (A) good thing in Hindustan is that it has unnumbered and endless workmen of every kind. There is a fixed caste (jam'i) for every sort of work...which has done that work...from father to son till now...680 men worked daily on my buildings in Agra, and of Agra stone-cutters only; while 1491 stone-cutters worked daily on my buildings in Agra, Sikri, Biana, Dulpur, Gwalior and Kuil. In the same way, there are numberless artisans and workmen of every sort in Hindustan. (*Baburnama,* p. 520)

By the reign of his grandson, the regulation of prices of building material, the wages of labourers, building estimates of houses, the weight of different kinds of wood, and even the manner of estimating losses in woodchips had been formalized (*Ain-e-Akbari,* I.p. 232 ff). Abul Fazl gave these details:

> Regulations for. house-building in general are necessary; they are required for the comfort of the army, and are a source of splendour for the government. People that are attached to the world will collect in towns, without which there would be no progress. Hence His Majesty plans splendid edifices, and dresses the work of his mind and heart in the garment of stone and clay. Thus mighty fortresses have been raised, which protect the timid, frighten the rebellious, and please the obedient. Delightful villas, and imposing towers have also been built. They afford excellent protection against cold and rain, provide for the comforts of the princesses of the harem, and are conducive to that dignity which is so necessary for wordly power.
>
> Everywhere also Sara'is have been built, which are the comfort of travellers and the asylum of poor strangers. Many tanks and wells are being dug for the benefit of men and the improvement of the soil. Schools and places of worship are being founded, and the triumphal arch of knowledge is newly adorned.
>
> His Majesty has inquired into every detail connected with this department, which is so difficult to be managed and required such large sums. He has passed new regulations, kindled the lamp of honesty, and put a stock of practical knowledge into the hands of simple and inexperienced men. (*Ain,* I, p. 232)

It was soon after Akbar's reign, in the 1620s, that the Danish traveller Olaffson visited Tanjore and praised the masons and artisans of that city. How, one might wonder, did these numerous artisans subsist in the lean years? Perhaps not very differently from their descendants in British India in the nineteenth century, who took to agriculture or moved to other towns which were on the rise.

Earlier, while that dynasty of citadel-builders, the Tughlaqs, were raising the massive buildings which today constitute the bulk of the Archaeological Survey's properties in Delhi, there was equally massive building activity going on in the south. In 1320, stated an inscription, 'the Governor had a spacious mosque built at Vijayapuri (Bijapur), the Benaras of the south' (quoted in Eaton, p. 15). It goes on to say that 'Revaiya, the carpenter from Salotji, built it. The Malik gave him a field'. And shortly after, on the bank of the Tungabhadra was being raised the city with a mesmerising name Vijayanagara. In a telling phrase, Burton Stein suggested that 'in many ways Vijayanagara was more like a Muslim capital than a Hindu one in its monumental architecture and Muslim soldiers and its very urbanity, its markets, palaces, temples and mosques' (*C. Eco. H.I.*, I, p. 123). And as that city of victory collapsed under invasion, yet another city of victory—Fatehpur—was commissioned by the third Mughal, on the hills of Sikri. And at the time *that* city was inexplicably abandoned (from 1591) there began the construction of the Mughal capital of south India, Hyderabad, to relieve the congestion of Golconda. Near the Musi bridge (built in 1578) was laid out the Char Minar, the signature of this city, with an adjacent Dar-ul-Shifa and a Jama Masjid, which rapidly became a commercial entrepot (Sherwani in *C.Eco. H.I*, I, p. 445). To outdo its grandeur, Shahjahan in 1648 ceremonially inaugurated the city at Delhi named after himself—and in the far south, the Wadeyar rulers were laying out the spacious new cities of Mysore and Srirangapattanam.

Thus these rulers, who led charmed lives, created structures that lived for centuries. While most of them had peripatetic life styles, they built enduring monuments. Regional and local variations in material and style, pictorial representations of architecture in other countries, fascinated and promoted emulation by these 'cavalier architects'.[2] Interest in the built form could make individuals either intolerant towards the achievements of earlier builders, or reverent towards them. If Shahjahan pulled down many of the sandstone-faced buildings in the Agra Fort and substituted his favourite marble, an earlier ruler, Ferozeshah Tughlaq, had been careful to repair older buildings. In Tamilnadu earlier, the Chola queen Sembiya Mahadevi had ordered, when a temple was being rebuilt, that 'the old inscriptions recording grants, donations etc., of all earlier kings which had been damaged, be faithfully engraved on the walls of the new structure' (V. Dehejia).

Imitation and plagiarism was inevitable. Ideas travelled across the subcontinent, crisscrossed the mountains and roads and seas. Lalitaditya's Martanda Temple had massive Byzantine elements as well as details from the Gaur he conquered (Wink, pp. 250-1). The architecture of the thirteenth century Padmanabhapuram in Kerala had traces from China with which that coast traded so actively. Gujrati *jalis* and the Bengal roofs became part of Mughal buildings after those *subahs* were conquered by Akbar. *Sawan* and *Bhadon* rain-pavilions were common to Rajput and Mughal palaces. Rajasthan palaces had many strong Mughal derivations (Tillotson), and in the layout of Hyderabad, Giese found similarities with central Asian towns *which*, he suggested, were derived from old Indian town-planning (Ehlers-Krafft, p. 23). Indian artisans helped build Taimur's Samarkand, and were taken captive by Nadir Shah to build Shiraz. In the eighteenth century the Jats plundered Agra only to replicate its spirit at their capital, Deeg. The 1000-pillared halls described in the *Vastushastra* and found at Persepolis took shape in thirteenth century Tamilnadu palaces and at Siri (the Khilji capital), in fourteenth century Vijayanagar and seventeenth century Madurai. Without visiting Europe, Shahjahan was fascinated by the *baldachino* of the German kings (Koch, *Mughal Architecture*, p.94). He also had a strong sense of competition with Shah Abbas' Isfahan. But when Isfahan was built, it was said:

Isfahan is half the world
Provided Lahore is not there. *(Quoted in Md. Saeed, p. 5)*

Later, Shahjahanabad became a reference-point for other towns.

V. URBAN DWELLERS

Inasmuch as historic towns in India generate nostalgia,if the early historic cities have a reputation of being well laid out, the 'medieval' town connotes an attractive 'life-style'. The people of these centuries appear to us more three-dimensional than those of earlier times: many elements of their costumes, food, and arts are still very much with us, and the contrast of their towns—lively without being overpowering, bustling without being polluted—to those we live in today, all create a craving for a return to that past.

We have already seen how easily a basic urban settlement was knocked together, and that the functions of trade, manufacture and nurturing of shrines went on irrespective of political changes. The layout of towns varied with climate and got modified over time, as the number of inhabitants increased. All over India, there was a basic common pattern—a *qala/ kot* at one side, with an adjacent *shahar/ petta*; the citadel was usually on a river, so that the rulers had an independent entrance-point. One suspects that in the structuring of a town's morphology, and its maintenance, there was no over-rigid regulation from above. An irritated or discontented citizenry was not something one encountered in these centuries (excited, disorganized townsfolk, yes, but revolt against the regime, no). The official component of towns was most elaborate in the provincial capitals *diwan, sadr, qazi, bakshi,* treasurer, and *faujdars* to guard the town: Ahmedabad under the Mughals had three, each with his own congintent, overseeing a fixed number of *puras* and adjoining districts (Naqvi, p. 92). The effective ruler of the town was the *kotwal.*

The urban folklore in all cultures has accounts of the gullible small-town man or rustic, taken in by crafty people in the wicked city. 'The Subedar of the Cot' (narrated in Rao, Shulman, Subrahmanyam, p. 13 ff) is an entertaining example from the seventeenth century. The *waqi'a* of Sheikh Rizqullah Mushtaqui (sixteenth century) has many anecdotes about gullible individuals taken in by tricksters in big towns. But all is well in the end, and justice is done by the king or the *kotwal*; the latter is punished if he cannot bring the culprit to justice. The *kotwal's* responsibilities were clearly set out in Abul Fazl's *Ain-e-Akbari*—a remarkable list of departmental responsibilities, together with discretionary powers of regulation, and of distributing largesse from the treasury to scholars and widows, (Waqi, p. 18). In Tanjore taxes were collected for cleaning the streets (for which every street-door was counted as a house). One of the most graphic pictures of a *kotwal* who became a sinister tyrant is that of Ghasiram of Pune under the Marathas (Tendulkar).

Gardens of Paradise

The beauty of individual towns was the result of a happy combination of natural landscape, individual efforts and some regulation. Pelsaert, a citizen of Holland, the country of small towns, dominated by the bourgeoisie, was as impressed by Agra as his contemporary Olaffson by Tanjore. He wrote:

> The city has no regular plan. The reason is its sudden growth. The luxuriance of the groves all round makes it resemble a royal park rather than a city, and everyone acquired and purchased the plot of land which suited or pleased him best. Consequently there are no remarkable market-places or bazars as in Lahore, Burhampur or Ahmedabad, but the whole place is closely built over and inhabited, Hindus mingling with Muslims,

> the rich with the poor... The breadth of the city is not as great as its length, because everyone has tried to be close to the riverbank and consequently the waterfront is occupied by the costly palaces of all the lords... The nobles surpass ours in magnificence. They build gardens for their lifetime and tombs for after their death (F. Pelsaert, p. 1).

For Mysore and Srirangapattanam, apart from the temples, palaces, armoury and stables, there are vivid descriptions of the streets—the two main ones in each city were named after the Sun and the Moon, lined with highly ornamented mansions of the chiefs. There was a market-street, a street for the Brahmins, others for ministers, for musicians, for financiers, for physicians, for dancing girls, for barbers, wrestlers, fishermen, tailors and many other vocations.

> With fruit trees, with houses as high as hills, was the city fitted; and with cows and Brahmins...with temples and fine elephants... (N. Subba Rao, p. 239).

Verdure was as important in laying out buildings as was stone and brick. Gardens recalled other places, even anticipated paradise. Jahangir's Agra had gardens that had originated much earlier.

> There in that charmless and disorderly Hind, plots of gardens were laid out with order and symmetry, with suitable borders and parterres in every corner, and in every border rose and narcissus in perfect arrangement (*Baburnama,* p. 532).

If the Mughals simulated the garden of paradise, Pieper would have us believe that the Bari Mahal garden planted by the Maharana in the new city of Udaipur (1599) was not simply for aesthetic effect but also to simulate the *Kalpavriksha* of Mount Meru; Maunbari in Amer fort incorporated Mughal water-channels and *chadars,* as also did the Ajmer and the Deeg gardens. Formal gardens were gifts from the rulers to the people. The mausolea of the Sultanates in north and south India, and of the Mughals, later copied by the Rajputs in their *chhatris* (also set in gardens) were open to everyone. There was none of the apartheid of gardens reserved in later centuries for Europeans. Also, the major monuments were employment-generative. When the Taj Mahal was built (1643) the gardens were surrounded by squares, serais, bazars and workshops, all adding up to being a large town, Mumtazabad, with endowments to maintain the garden and the mausoleum. (*Shahjahan-nama,* p. 299).

Private and Public

Benevolo described Arab towns as having private houses and only two categories of public buildings—baths and mosques. But there were more: in Shahjahanabad's first ten years, apart from the Jama Masjid, a bazar, a college and a hospital had come up (*Shahjahan-nama,* p.531). The *maidans* served as the stadia and gymnasia, which Benevolo found absent, the street and the *chowks* served as basilicas, theatres and popular fora.

> At Akbarabad, the area just in front of the gate of the fort was congested with various public buildings, offices and private dwellings, leaving no open space for a forecourt (*jiluakhana*). Therefore, when nobles came to pay their respects, there is great inconvenience because of the concourse of men and horses, specially on Id, Nauroz and other festivals, and during royal processions. The people's lives were endangered. Therefore his Majesty ordered that a spacious plaza, which the natives of Hind call *chauk,* be constructed in front of the Fort Gate, with a large bazar in octagonal Baghdadi style, one side to be a mosque built from (Princess) Jahanara's personal funds. The ground is chiefly royal domain. Of what little was the property of others, the owners were gratified by receiving 10-15 times the actual value, or neighbouring estates out of the crown lands (*Shahjahan-nama,* p. 205).

Religious sanction encouraged the setting up of *serais, madarsas,* hospitals and mosques. The land they were built on were designated as *waqf*—the only inalienable category of urban rental property, a practice begun in the eleventh century with the Seljuks (Hodgson, vol. II, p. 51). This was not very different from the south Indian towns; corporate life was in evidence in *mathas* with *chhatrams,* where people were fed, temples, *chavadis* ('chowltries') and the *kuta* (an assembly for religious purposes (Subba Rao, p. 240).

Streets, as well as *chowks,* were arenas for social exchange. Delhi, Lahore and Agra, the three prestigious capital-cities of the Mughals, had paved streets (Deloche, vol. I, 104.), in contrast to the slushy streets of Surat. (In Europe paving was introduced in Paris in the twelfth century: Mumford, p. 309.) *Ratha*-streets were a strong feature of the urban landscape, from Orissa towns to Kerala's Thrissur. Weavers' streets, shaded with trees, were distinctive. In the weavers' quarters of south Indian towns, there were 'long houses without walls, within which are tables as long as houses', and the weavers used to 'sit there all day until the evening working with great art and a gleeful chatter' (Olaffson).

The low-rise character of most Indian towns was sometimes read as implying some inferiority in construction or imagination. Bernier noticed this and was quick to correct it. His words were a lesson for later planners and architects:

> In treating of the beauty of these towns, I must premise that I have sometimes been astonished to hear the contemptuous manner in which Europeans in the Indies speak of these...They complain that the buildings are inferior to those of the Western world, forgetting that different climates require different styles of architecture...The cities of Europe may boast great beauties; these, however, are of an appropriate character, suited to a cold climate. Thus Delhi also may possess beauties adapted to a warm climate...now, suppose the streets of S.Jacques or S. Denis transported hither, with their close houses and endless storeys... would they be habitable? or would it be possible to sleep in them during the night? (Bernier, p. 240).

'That tumultuous city' was the Persian Ali Hazeen's description for Delhi in the eighteenth century (p. 294). Indian cities were clearly quite crowded—inhabited densely and with crowds on the streets and *chowks.* And walled against the street were the *havelis,* havens of tranquillity and elegance, miniature kingdoms where a hierarchy of family and dependents lived, often incorporating the cottage-industry of *karkhanas.*

In southern towns, the merchants had spacious houses set in gardens. In some compactly laid out towns, like Tanjore and Pune, houses were built vertically even up to seven storeys (cf. Rao, Shulman, Subrahmanyam, p. 13). There were no separate sections of the town assigned to the rich or influential, and proximity to the royal citadel was not necessarily a sign of status. In Agra, Lahore and Delhi, the sections between the major streets were broken by winding lanes which shaped the *kutchas* and also created wind-passages and thermal control. The *kuchas* formed small areas enclosed for security by precinct-gates. In Delhi, each of the 12 *thanas* of the city were atomized into 100 *mohullas,* which are still recognizable (Ehlers-Krafft, p. 21). Even more densely packed and sub-divided were the *pols* of Ahmedabad. Additional *puras, ganjes* or wards would be laid out or demarcated by the rulers. This could be seen in north Indian and Maharashtrian towns. In the south, where most towns were not enclosed by a wall, this did not have to be formally done.

There are no references to intra-city tension even in such crowded towns. This could be explained by the absence of separate areas for the rich and poor, and by the fact that each *mohulla* served as an organic unit of people of an extended family or of like occupation. As for tension which could arise from adjacent territories, in Islamic law the open space around a building could be built on only with the consent of the owner. Disputes would be settled locally by the *mohulladar* (Michell, p. 139). Unfamiliarity with customs could be taken advantage of: both the British and the French East India Company were helpless when confronted by groups belonging to the 'left-hand' (Telegus who migrated to Tamil country from the late fourteenth century (Rao, Shulman, Subrahmanyam, p. 73 and footnote), who had claims on particular streets and wanted to keep out the members of the 'right-hand' (Tamil) castes (Roche, p. 399). Barbosa (*c.*1515), describing Calicut, said that 'the Gujeratis have streets of their own, like the Jews in Europe'—which is not a valid comparison, since the Gujerat *vanias* did not suffer any of the disabilities that Jews did.

The Muslim inhabitants of towns, particularly those who were first or second-generation immigrants, had associations, mental and actual, with urban areas, since in west Asia the rise of Islam had a strongly urban bias. The *mahalle* of the Arab world marked the different slices of urban land apportioned to different tribes. Thus, an individual would be a citizen of a given town, but he would have strong links with members of his 'tribe' or family in other towns and other countries. This was also true of mercantile communities in India, like Marwaris and Parsis. Banarasi, a jeweller who lived in the sixteenth century, wrote about Fatehpur Sikri:

> I set out for the new town (Fatehpur) with the whole family. At Fatehpur I enquired for the quarters where the Oswal Jains had their houses. Bhagvati Sah made room for us in his house and I spent many happy days there. (Banarasi, p.22)

Life-style

Since property-control did not confer the assurance of permanence, as it did in Europe from the sixteenth century (Mumford, p. 416), wealth was expended not on real estate but on personal acquisitions, on extravagant life-style and on patronage of arts and crafts. This patronage cut across caste and religion. By contrast to the Ottoman Empire, where Christians and Muslims were polarized culturally, in Indian towns cultural expressions brought diverse groups together, at both popular and elite levels. Such activities bore no correlation to the political fortunes of individual cities. In fact, the arts might have thrived in periods of distress. About theatre, for example, it was suggested that 'many theatrical forms have grown in India precisely at a period of political and social unrest...and forged links of mass contact through drama' (Vatsyayan, p.36). From the sixteenth century developed the dance forms of *yakshagana, jatra,* and *tamasha* (a word of Persian origin), which linked cities and small towns. These created an impression on visitiors like Olaffson, who said, 'not in bright daylight but at night do they hold their festivals, dancing and strange games'.

At a more exclusive level, rulers and nobles patronized art forms like 'chamber' dance or music, painting and textile and costume design, usually of foreign origin. Sultan Firoze Bahmani (1397-1422) established a direct link with west Asia: he 'yearly sent a number of empty ships to the Persian Gulf (to) bring soldiers, artists and administrators to serve at his court' (Eaton, p. 42). There are accounts of thousands of musicians, scholars, poets, calligraphers and master artists flocking to Bidar (*ibid,* p. 71). Similarly, in the eleventh century, says Al-Beruni, invasions led to pandits fleeing to Varanasi and Srinagar (Al-Beruni, vol. I, p. 22).

The men of consequence at the Sultanate and Mughal courts were like the colourful characters of the European Renaissance who combined in themselves the roles of diplomat, warrior, scholar and patron. The art of poetry had a wide reach, as the popularity of Amir Khusro's verse in Hindawi and the new language of Urdu, translated and sung all over central Asia, will testify.

The same Urdu created links and bred rivalries between the cities of Delhi, Hyderabad and Lucknow. Classical music and dance—both courtly and temple-centred—did not travel beyond India till much later. In these centuries the musical tradition divided into Hindustani and Carnatic, with *gharanas* which became historic, associated with specific towns and families. Likewise, poets, too, were associated with specific towns.

Landscapes, skylines, cultural forms, and craft products gave each city a distinctive character. The inhabitants were conscious of their town's identity, and there was an implicit sense of competitiveness. In countries of west Asia, the names of town and region were often the same (e.g. Misr); but, by contrast, Indian towns acquired an anthropomorphic quality. Like Madurai, the image of which in Sangam literature had been very powerful, Varanasi, Delhi and Lahore had the same quality. These cities were seen as having qualities beyond their administrative distinctness. 'Dehlavi', 'Badayuni' or 'Sirhindi' were suffixes attached to the names of individuals to fix them in place.

Rulers, big and small, enjoyed showing their cities to visitors. Their hospitality was unstinted, as acknowledged by Paes at Vijayanagara and Bernier at Shahjahanabad. Olaffson who led a Danish expedition to Tanjore said:

> When the king received the news of their approach, he had his palaces decorated ... This royal city is large and of a great circumference, with eleven gateways... The King asked his fighting men, called *taliaris*, to line a certain street all the way from the city walls to the king's hall. He entertained them with much honour for a fortnight',

and, with a childlike simplicity, 'he displayed to them all his glory, jewels and treasures'.

Cities of Joy and Distress

To some, towns provided jobs; to many they served as refuge. In times of political instability or famine, towns were flooded with immigrants. Whether these refugees clung to the outer wall, or whether they worked their way into the town, is not clear. Many major building projects were famine-relief works. In most power-struggles, towns were often threatened. Battles, though, generally occurred in open areas, not in the towns. But there were episodes of invasion, and most of them gave rise to vivid memories which lasted centuries. Some memories of destruction, like those of victory, survive in town-names: after the Hoysala city of Dwara-Samudra was destroyed in 1311, it became known as the 'Ruined City' (Halle-vidu/Halebid); Kollegal, near Coimbatore, was referred to as 'the plundered town'. There are examples of destruction in triumph or anger: of Vijayanagara in 1565, of Bijapur in 1684. Three and a half centuries passed between Taimur destroying Ferozabad (Delhi) in 1398, and Nadir Shah letting his soldiers loose in the nearby Shahjahanabad. But the picture of Delhi as a much-invaded city was a strong one in the popular mind. This was strengthened by the *Shair-Ashoob* genre of Urdu poetry—'the dirge for the city'—which had stereotyped images and an obviously ahistoric character.

At time of invasion, the inhabitants had two options—of digging their heels in, or fleeing. The latter was common:

> If the people of a large town, one inhabited for years, even, flee from it, they do it in such a way that not a trace or sign of them remains in a day. (*Baburnama*, pp. 487-8)

Three hundred years later, Colonel Wilks described such flight in south India—this was locally called the *wulsa* (Wilks, p. 344). The reason for the flight was the fear for person and property— pillaging was common. Banarasi describes vividly the panic in Jaunpur when there was a fear of attack. While the Sultan made swift preparations for a military encounter, 'the civil population...took to flight and the city soon became deserted. Only the jewellers, huddled together..., still remained in town' (Banarasi, p.23). There is a dramatic account set in Puri in the seventeenth century, when Keshav Das Maru attempted to rob the Jagannath temple—his forces confronted those of the Khurda raja, both mounted on temple *rathas*

(Kulke, p. 75). Another cause for exodus was an epidemic, when people would flee, returning only when the disease had run its course.

Town walls were useful for controlling the entry into and egress from towns. From the sixteenth century walled towns became increasingly common, in response to increasingly destructive means of warfare. Cannon was used in Gujerat in the late fifteenth century (Rao, Shulman, Subrahmanyam, p. 226); but its use, supplemented by the raising of military contingents trained by Europeans or Africans, increased sharply after the Portuguese arrival. Many older towns acquired walls—for example, Tanjore, the Chola capital from ninth to twelfth century, which had been an open town. Maratha Tanjore in the eighteenth century consisted of two forts—Sivaganga (said to have been built in the sixteenth century) and the large fortified circle of the city (built in the seventeenth century). Similarly, Srirangam had many concentric walls.

Indians did not match their hospitality by travelling abroad themselves. But some 'Indian' towns could be found beyond the natural frontiers—in Ajudhia and Angkor Wat in south-east Asia, and in sections of towns in central Asia. In the eighteenth century Astrakhan, Baku, Herat, Kandahar, Kabul, and some towns in Iran had Marwari and Khatri colonies. In Astrakhan, 'Gostiny Dvor', a stone arcade near the centre of the city, housed the shops and apartments of Indian merchants (S.F. Dale in S. Bose, p. 145). The mirror-images were the European forts on the Indian shores built by military engineers like the French Vauban. They built on a smaller scale fortified towns on the pattern of Lorient.

Summing Up

The eighteenth century was a period of major upheavals. The north Indian-west Asian balance of power shifted with the rise of Persia and the decline of the Mughal empire; and in south India there was an unstable equilibrium between a conservative Nizam, ambitious Maratha chiefs and Mysore rulers. Both these developments were in turn affected by the final substitution of British and French mercantile companies in place of the Arabs and Chinese as the chief carriers of trade. Suddenly, the small European forts on the coasts appeared sinister and powerful. But with the old Indian habit of always looking inland, and the inability to appreciate the potential of sea-power, the *nawabs, rajas* and *palaiyakars* built their little capitals and rejoiced in them. They would have raised their eyebrows incredulously at any suggestion that the great days of Delhi, Agra, Lucknow, Surat, Murshidabad, Dhaka, Srirangapatnam and Lahore were numbered, and that the towns of the future would develop in a different context. The Indians who kept their heads above water would be the future merchants and landholders, many doubling as *dubashes* (interpreters) to the Europeans. Ananda Ranga Pillai was to be the representative of the new successful Indian town-dweller, just as his master Dupleix was to be typical of the new European merchant in Asia, who dreamed of empire and not of trade.

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NOTES

1. Chinese, West Asian and Meso-American towns were also distinctive at this time, but it is for the European towns that we have the best researched histories.
2. *Kavalier-architekten* is a German phrase used to describe 'individuals who possessed the intellectual and financial means to create and build an architecture of their own' (Heinz Horat).

CHAPTER XV

Women Saints in Medieval Indian Society

Vijaya Ramaswamy

I. INTRODUCTION

The most powerful characteristic of the medieval age in India was the Bhakti movement. The movement began in the sixth-seventh century in south India with the rise of Hindu devotional cults, gradually spread throughout the country, and lasted till the sixteenth-seventeenth century. Most of these cults were heterodox and reflective of an inner social ferment.

The Bhakti movement in India, by and large, was marked by (a) the rejection of the then existing ritual hierarchy and Brahmanical superiority; (b) the use of the vernacular in preference to Sanskrit (the language of the elite); and (c) the emergence of the low-caste 'non-literate' persons like Ramanuja Dasar, Pillai Uranga Villi Dasar and Kanaka Dasar in the south and Kabir, Raidas, and Dadu in the north as great spiritual leaders. There was large-scale participation of peasantry, artisans, and other lower classes as well as of ritually inferior but economically powerful groups like merchants and craftsmen in these devotional movements.

It is of crucial significance that this was also the period which saw the emergence of women saints on an unprecedented scale. Secondly, the confluence of the Bhakti and Sufi streams in the medieval period laid the foundation of a composite Hindu culture.

This paper proposes to explore the emergence of women saints in Hinduism in the context of the medieval social milieu. The analysis of the role of women saints will involve both theoretical and pragmatic stances and, to a certain extent, reflect both the insider and the outsider perspectives. Thus, a specific section on the image of women as perceived in the writings of Dadu, Kabir and other male saints has been included to illustrate the emphasis on chastity, motherhood and the negative male perceptions of women's beauty and sexuality. However, some male perceptions like that of Dharanidas, in the context of Bhakti, do tend to take women out of the traditional role model.

The third section of this paper deals once again with two diverse perspectives. One, the reiteration of the traditional patriarchal role model by women saints like Bahinabai, who were basically conformists, and two, the rejection of the traditional role model by rebel saints like Lalla, Meera and Akka Mahadevi. The emergence of these latter women saints indicates a shift from the orthodoxy of Shankara and the dominance of Brahmanism to popular devotional movements. Women saints (whether they conformed to patriarchy or rebelled against it) and the marginalized males like the Shudra saints could hope to create a space for themselves only within the popular religious streams like the Bhagavata movement, Virasaivism or the Kashmiri Rishi movement.

This study will focus on the emergence of women saints in Hinduism but Sufi women saints will also be discussed in the overall religious context. Special emphasis will be laid on the geographical region of the Deccan (the area south of the Vindhya mountains) in the description of the social milieu and on the women saints of medieval south India. The Deccan was undoubtedly the centre of spiritual activity from the seventh to twelfth century. While the Indo-Gangetic belt was going through a period of internecine conflict and political instability, the Chera, Chola and Pandya rulers in south India were ushering in a period of prosperity and expansion. As Brahmadeya (fertile lands given to Brahmins) increased there were temple-centred, Sanskritized, Brahmin dominated orthodox movements, on the one hand, and folk religious movements like those of the Pasupatas, Saktas and Kalamukhas, on the other. These two streams occasionally met as in the Azhwar and Nayanar movements of the Tamil country. It is within the trope of popular Hinduism that one has to look for women and depressed classes as well as the confluence of Sufism and Bhakti. While maintaining the focus on south Indian women saints, the social milieu of northern India and the life experiences of north Indian women saints will be used as points of comparison with the south.

From the latter part of the twelfth century the Warkari and Mahanubhava movements in the Maharashtra region become seminal to religious movement, especially in the gender context. The focus shifts to northern India from the twelfth century onwards.

Further, the paper seeks to juxtapose the theoretical and traditional role perceptions of women against that aspect of social reality which these women saints represented. To what extent did they function within the traditional paradigm and to what extent did they manage to break out of it? How far did the status of women in medieval society reflect their economic position in terms of the production process and the ties of dependence? In this connection, how close is the link between everyday technology, popular science and the dissemination of religious ideas? What broad impact did their lives and ideas have on society? These are some of the issues which this paper hopes to raise and to explore.

II. THE SOCIAL MILIEU

Indian society being largely patriarchal, the position of women has been regarded as inferior. The secondary role assigned to women became progressively emphasized in medieval India. The birth of a son continued to be looked upon as a highly desirable event, while that of a daughter was deplored. Two inscriptions from Chennapatna and Nagamangala taluqs dated in the eleventh and twelfth centuries AD stated that a good son is 'the lamp of the family' as the moon is the lamp of the night, the sun the lamp of the day, and dharma the lamp of the three worlds. But as regards the usefulness of daughters, one encounters an eloquent silence!

The repeated Muslim invasions from the eleventh century onwards and the establishment of the Sultanate in the north and the Muslim kingdoms in south India led to further deterioration in the status of women. Indeed, this was true of not only the Muslim invasions but every foreign invasion which invariably led to the orthodox society closing its doors and imposing greater restrictions on women. Fear of the invaders' attacks on their women was a constant threat to orthodox Hindu society. It was believed that any relationship between Hindu women and the outsiders would result in the admixture of castes *(varna sankara)* and the breakdown of social order. This led, on the one hand, to the imposition of greater restrictions on women and, on the other, to an increased exploitation of them. This was specially true of upper caste women and urban women, but the penetration of Muslims into the countryside and the enduring presence of Muslim officials there also affected the position of rural women, though to a lesser degree.

Unwelcome Daughters

The birth of a daughter was unwelcome because she was a source of expense, trouble and anxiety to her parents, since they merely had custody of her till her marriage. Some of the Tamil proverbs illustrate the obvious preference for boys over girls, although being 'soft' evidence, it is not possible to locate these proverbs within a time-frame. They are cited here since they are broadly indicative of traditional values in south Indian society. One proverb, 'chan pillai aanaalum aan pillai', means that 'even if he measures but an arm's length the child is a male child' (rather than a female), indicating that being male is itself a sufficient virtue. According to another, 'anju pen pirandal arasanum aandi aavaan', 'even a king would turn a beggar if he had five daughters'. The proverb suggests that girls constitute an economic drain because, while no material returns can be hoped for from them, one also has to spend a fortune in terms of their dowry or groom price at the time of their marriage.

According to the scriptures and orthodox tradition, a daughter's marriage had to be performed before she came of age (i.e. before she attained puberty). Child marriage was dictated by the social and moral codes of the times and could be flouted only at the cost of moral ostracism. This was because a girls sexuality was considered dangerous and a force that had to be contained within the bonds of marriage. In fact, custom and tradition stipulated that she be modest and subdued so that she did not attract male attention. The point is again illustrated by ancient Tamil proverbs. One says 'pugai ilai viriththal poachchu, penpillai siriththal poachchu': just as tobacco leaf loses its freshness if it is kept open, so does a girl her modesty if she laughs. Another proverb says 'adikkadi siriththavalum vedukkenru nadandavalum vesi': a girl who laughs too often and walks too provocatively, is a prostitute![2]

The north Indian milieu presented a picture that was even more grim. In fact the Rajputs and other social groups in northern India experienced the greatest threat from the invaders. For the warring clans of Rajputana, the crying need was for soldiering sons, not daughters. Secondly, north Indian society in general experienced the greatest threat to their women from the invading armies, and hence child marriages and *purdah* (veiling) were most prevalent here. These customs were compounded by other severe restrictions on women in an even more accentuated form than in the south. Considering that the birth of daughters gave rise to grave social problems, it is not surprising that the Rajputs indulged in the unnatural and horrendous practice of female infanticide—an evil that persists even to this day in certain backward areas of Rajputana and other states.

The practice of polygamy prevalent in most parts of urban India, demeaned and reduced the position of women even further. A woman was not considered a man's co-equal but an object of enjoyment. The practice of having many wives was widespread among the royalty and the nobility and not uncommon even among the ordinary people. A fourteenth century writer Mallanna in his work *Rukmangada Charitramu* makes statements such as 'Disobedience on the part of the wife lands her in hell. She should not be angry if her husband desires the company of another woman.'[3] A Tamil proverb which shows the prevalence of polygamy among the common people, 'mudal manaivi daaram, erandaam manaivi bharam, moonram mannaivi ghoram', means that the first wife is a partner, the second a burden and the third an abomination.[4] It is interesting to note at this point that Islam explicitly sanctioned four wives (probably a sanction demanded by the exigencies of a society where the male population was being annihilated in battles and the widows were left destitute).

This was also the time south India began to abound in erotic literature written in the regional languages. The tenth century work *Jivaka Chintamani* written by Tiruttakka Devar graphically described the many love affairs of its prince-hero Jivaka and concluded with his rejection of worldly pleasures and acceptance of monkhood in Jain tradition.[5] *Kulamani* by Tolamozhi, another contemporary work, was also along the same lines. *Yasodhara Kavyam*, a short epic of 300 verses, written a few centuries later, sought to prove that women and music constituted the greatest hindrance to man's spiritual progress.[6] An outstanding example of such literature in the Vijaynagar period was Vallabharaya's *Kreedabhiramamu* of the fourteenth century,[7] which told the tale of two young men seeking pleasure in Ekasilanagaram (modern Warangal). This was itself based on Tripurantaka's *Premabhiramamu*.

Veneration of Chastity

Women entered the homes of their husbands as child-brides and this enabled their conditioning into a position of helplessness. The women were illiterate and knew little else besides domestic skills. As it was the woman's role to serve in her home before marriage, so it was her bounden duty, her *dharma*, to play a role of subordination and servitude in the home of her husband and in-laws. A well-known saying in Hindi says that a married woman should leave her husband's home only on her funeral bier. The Telugu writer Mallanna says in the *Rukmangada Charitramu* that 'Wives should be glad when their husbands are glad and sad when they are sad.'[8] Chastity was regarded as the supreme virtue of womanhood and a chaste wife (*pativrata* in Sanskrit and *pattini daivam* in Tamil) was deified. It was considered auspicious for a wife to recall in the morning the chaste wives celebrated in legend and mythology. This prayer goes:

> Ahalya, Draupadi, Seeta, Tara, Mandodhari tatha
> Panchkanya smarennithyam sarva papa vinashanam.

Both Draupadi and Kannagi were venerated as goddesses in south India in memory of the power of their chastity.[9] Another such figure in Tamil folk tradition was Aadimandi, the daughter of Karrikala Cholan. She married a Chera prince called Aattanaththi who was a skilled dancer. Her husband was drowned while dancing on the waves of the river Kaveri but by the power of her chastity Aadimandi snatched her husband from the jaws of death.[10] Veneration of chastity was again another means of the orthodoxy for controlling female sexuality.

Two customs reinforced and strengthened the traditional role assigned to women. One was *purdah* or the veiling system and the other, more deadly practice, was *sati*. Purdah was common among the upper class Hindus and Rajputs in the north while in the south respectable women very rarely stepped outside the bounds of their home. Abdur Razzaq says that Nehal, the Mudgal beauty (the goldsmith's daughter who is popularly held responsible for the war between Vijaynagar and Bijapur) refused to receive the gold necklace presented to her by Deva Raya-I, for she feared that 'whoever entered the harem of Vijaynagar was never afterwards permitted to see even her nearest relatives.'[11]

As a result of the highly protected life led by family women, the only class of women on whom the foreign travellers like Paes, Nuniz or Barbosa commented were the courtesans or devadasis.[12] Prostitution was accepted as an inevitable aspect of social life and the devadasis or devaradiyar in the late-Chola and Vijaynagar period in fact occupied an important position in society and even enjoyed the privilege of direct audience with the king.[13] They also owned landed property and made large donations to temples.[14] One record states that Peruntiruvatti Kayilaikizhatti of Temangudi purchased 30 velis of land (200 acres!) and donated it to the Vedaranyam temple.[15]

The Abhorrent Practice of Sati

The life of a respectable woman ended with her husband. The practice of mounting the funeral pyre of one's husband was known as *sati*. The term and the practice were associated with Siva's divine consort Parvati who in her incarnation as Sati threw herself into the sacrificial fire built by her father Daksha because he had insulted her husband. This was therefore regarded as the ultimate act of devotion which a chaste wife could offer. The mass death of queens through self-immolation on the death of the king was known as *jauhar.*

The customs of *sati* and *jauhar* in northern India have been the subjects of many detailed and elaborate studies. Therefore I shall focus here on the more controversial aspect of *sati* in southern India. Contrary to popular belief, the *sati* was not a practice confined to Rajputana or to northern India—it was also prevalent in the south. The antiquity of the *sati* custom in south India has been a matter of much discussion. It is usually believed that *sati* was not indigenous to the south but came in only during the medieval period.[16] However, George Hart in his study of Sangam literature found evidence of *sati* in the *Purananuru* and elsewhere. The evidence offered was nevertheless extremely limited and not conclusive, except for the *Purananuru* reference in which the wife of a chief called Butaapandiyan said that she would prefer to die on the funeral pyre of her husband rather than lead the tortured life of a widow.[17] In the famous post-Sangam epic *Silappadikaram,* the Pandyan king Nedunchezhian's wife died on getting the news of her husband's death. The Tamilians regard this as the most superior form of sati *talaikarpu.* In *Manimekalai,* the sequel to *Silappadikaram,* Aadirai the wife of Saduvan committed *sati* but the fire did not burn the chaste wife because her husband, unknown to her, still lived!

There are some known instances of *sati* in the Chola period, the most famous being that of Vanavanmadevi, the mother of Rajaraja-I. A Kannada poem dated AD 1057 narrates the passionate appeal for self-immolation by Dekabbe, the daughter of a chieftain of Nunganad.[18] In an inscription from south Arcot belonging to the reign of Virarajendra, the widow ranted against those who sought to prevent her from committing *sati.*[19] The evidence is still very sparse for the pre-Vijaynagar period, and one would tend to agree with Nilakantha Sastri that 'the references are so few that it can hardly be regarded as a common practice in the Tamil country.'[20]

There is plenty of evidence to indicate that *sati* had become an honoured custom in the Vijaynagar period. Nicolo de Conti said about the Vijaynagar king Devaraya-II, 'He takes to himself twelve thousand wives, of whom four thousand follow him on foot wherever he may go and are employed in the service of the kitchen. The remainder are carried by men in palanquins of whom two thousand or three thousand are selected as his wives on condition that at his death, they should voluntarily burn themselves with him which is considered a great honour for them'![21]

The idea behind this barbaric custom was that the faithful wife should continue to serve her husband even in the hereafter. Even among the Lingayats, also called Jangamas or Virasaivites, it was the practice to bury a wife alive along with her husband in a sitting position. An early reference to this inhuman practice occurs in the writings of Abdur Razzaq in the fifteenth century.[22] A woman who consented to this became deified. The deification of a *sati* was also practised among other castes and the couple became the ancestral gods of that particular family. The famous Vijaynagar poet Srinatha in his *Palnattu Viracharitra* wrote that seven generations benefited from the *sati's* supreme sacrifice.[23]

The Plight of Widows

The lot of those women who opted to remain alive after their husband's death was miserable. They had to tonsure their hair, divest themselves of all ornaments, and not be seen by people since the very sight of them was considered inauspicious. References to the rigours imposed on a widow occur in the Sangam literature itself. In the verse from the *Purananuru* cited earlier the widow about to commit *sati* says :

I am no woman to suffer austerities,
eating for food
velai leaves
boiled with tamarind
with white sesame paste
and a squeezed ball of rice, untouched by fragrant ghee...
and to sleep on a bed
covered with stones
without even a mat.[24]

This situation remained unchanged even in the medieval times. Purandara Dasa presented the heart rending plight of a widow in one of his compositions beginning with the phrase: 'Ramananilada nari, parara kannige Mari':[25]

A woman without husband
is like Mari, an evil goddess.
Her life will be like a knife
held at the throat, razor's edge.

She can't come out lest people comment
... but they still talk, God only knows.

She will be held cheap by society
Her life worthless, wretched in all respects.
In-laws call her murderer, parents curse.
Her words treated with contempt.

She will do all the servile work
But still be shunned as evil omen.
Accuse her of idling, being a burden...

O thou, with fortitude, in thy loneliness
Remember the Lord, Purandara Vittala.

The commentator Mallanna writes that according to the law givers, 'a widow's blessings are poison, no one should accept them.'[26] It is interesting to note that at the height of the Bhakti movement in the south, one of the contentions between the Vadagalai and the Tengalai was the status of widows. While Vadagalai, the orthodox school, supported tonsure quoting Manu, the Tengalai opposed it quoting *Parasara Smriti.*[27] In fact it was only in the nineteenth century that social reformers like Raja Ram Mohan Roy tried to alleviate the lot of the widow. A sensitive and thought provoking film on the fate of the Hindu widow was produced in the Kannada language in the early 1980s titled 'Phaniyamma'. Interestingly, a widow's life depicted in it was not very different from the graphic description given in the *Purananuru.*

Two primary factors behind the social exploitation of women were their lack of education and economic independence. The famous poet and author Rajasekhara, writing in the ninth century AD said that education among women was confined to the royalty, the nobility and to some extent the priestly Brahmin class, and also the class of dancing women, the *ganikah.*[28] In general, women were excluded from the *upanayana* or thread ceremony which marked one's entry into the *gurukula,* the traditional school. Therefore, their unfitness for the thread ceremony also rendered them unfit to receive education. The twelfth century commentator Vijnanesvara in his *Mitakshara,* which is a document of the social and legal code of the period, observes that for women, marriage stands in place of *upanayana* and *brahmacharya ashrama* and women like shudras, being illiterate, have no capacity for *japa* or meditation.[29]

Not much is known about the property rights of women in the medieval period. In south India the land called *manja kani* specifically referred to landed property given to a girl when she got married. One of the earliest cases of widow's right to inherit property comes from Gujarat in the period of king Kumarapala in an inscription dated AD 1150; and it says that the king showed a magnanimity that had not been displayed even by Raghu, Nahusha and Nabhanga. The Daayabaaga school of Bengal recognized the right of women to hold, buy and sell property.[30] The *Mitakshara* of Vijnanesvara recognized the right of women to inherit but clarified that it was only the right to usufruct (use and profit), not the right to sell. It also stated that a woman's property is inherited wholly by the daughter and the daughter's daughter.[31] A thirteenth century inscription of the period of Pallava chief Kopperunjingadeva from Tillai amman temple, Chidambaram, referred to a sale of land owned jointly by the male and female members of the family.[32] Further reinforcement of women's right to property in the later medieval period comes from the *Saraswativilasa*, a Sanskrit treatise on *Dharma Shastra* written in the sixteenth century by Lolla Lakshmidhara a luminary of Prataparudradeva's court. It gave sons and daughters equal rights over their parents' property and the wife exclusive rights over *sthridhana* (land and wealth given to the bride by her parents) as well as a share in her husband's property.[33]

A very interesting explanation offered for the spate of enactments recognizing the rights of women to property in medieval south India was that the law-givers and jurists of this age were themselves adherents of Virasaivism, which was liberal in conception and egalitarian in outlook. The influence of the Bhakti movement in favourably affecting women's property rights was felt much more in south India than in the north.

The Traditional Role of Women

The role played by women in the production process was a major factor in determining their place in society. Literature from very early times suggests that rural women had a more active share in the economy than urban women. The planting of seeds and winnowing of paddy were done entirely by women, and this is largely true even today.[34] Women in the countryside also assisted in the irrigation of fields. The *yettram* or picota, the device for lifting water from wells, was worked by women walking up and down the balance, coming up to the fulcrum to immerse the bucket in water and walking back to bring up the water and empty it on to the fields. A whole genre of folk music developed around this called *yettrapadalgal* or *temmangu*. In one such song the woman laments the fact that women have no rights and no redress against unfaithful husbands:

> Is there any such place in the world where women have rights?
> Is there any light? Only the cremation ground burns bright
> With his charming smile, he asked me for money
> Charmed by his smile, I lost all I had.[35]

Among the crafts, woman played a more important role in rural domestic crafts that in urban crafts. In the weaving industry, cleaning, combing and carding of cotton yarn as well as its spinning was the work of women. Spinning was exclusively women's work and the main source of livelihood of widows and destitute women. In Sangam texts these women were referred to as *parutti pendugal*, literally meaning 'cotton women'.[36] The remarkable traditional continuity of widows spinning yarn can be seen by a practice still prevalent in traditional weaving areas in south India. In district Salem the Gaunder perform a ceremony called 'mangala ani kalai chadangu', by which a widow is divested of all the auspicious symbols of marriage. On that day, her father or a close relative gives her a ball of cotton and a spindle and tells her:

Here is the spindle made by the smith
and fine cotton grown in Koranadu
Live a hundred years, my dear,
spinning for your livelihood.[37]

Women also predominated in dairy farming which is again a rural industry. However, in all the major crafts, women played an inferior and subordinate role, although an essential one. This is true of pottery making, metal working and other crafts. Their role in the production process especially in the urban set-up was almost always complementary, never independent. This was reflected in their social status which was markedly inferior to that of men.

The situation in rural India was definitely very different from the towns. Here the women were not subordinates but almost equal participants in the production process. The considerable participation of women in the rural economy had a bearing on their social status. The rural women also enjoyed rights over their *manjakani* property (land given to a woman by her parents at the time of marriage). It is of considerable significance that, while in the urban set-up the reference is always to dowry or groom price, in the countryside one finds reference to bride-price (called *parisam* in the Tamil country). Again, the demeaning practice of polygamy was prevalent in medieval times, not so much in the rural areas as in the urban areas.

How Men Saints Viewed Women?

Finally, the manner in which the men saints of the medieval period viewed women is best illustrative of the usual attitude of society towards women. According to them, both women and gold were to be shunned, being the cause of men's ruin. They always coupled *kamini* or woman (literally the embodiment of desire) with *kanchana* or gold (*pen* and *pon* are the Tamil terms, *hen* and *hon*' in Kannada are alliterations) as being the two main sources of worldly enjoyment and moral depravity. Several examples of this is to be found in the poetry of the Bhakti saints of both southern and northern India. The Saiva saint Sundarar (seventh century) who married two women—Paravaiyar and Chengiliyar—wrote that having fallen into the dragonets of the deer-like eyes of women, he hated married life: 'veruththen manavazhkaiyai vittozhinthen.'[38] Manikkavachakar (tenth century) berated himself for being swayed by a woman's cunning charms—black eyes, coral lips and pearly smile.[39]

Arunagirinathar, the famous Tamil poet-saint who lived in the fifteenth century, is himself said to have led a depraved life before his transformation, and his compositions especially in the *Tiruppugazh* and the *Kandar Anubhuti* warn spiritual aspirants of falling into the snare laid by beautiful women. He asks:

Should I be destroyed by the snare
laid by women with spear-like eyes?[40]

Elsewhere he says:

Associating myself with women and contracting
diseases, here am I, a low dog.[41]

Similar examples are also to be found in the Dasa poetry. Their social commentary on women is to be found in their devotional compositions as well as short poems called *suladi*. The examples given here from Purandara Dasa are the most illustrative of this genre. In the song beginning with the words 'Hennegichchaisuvare mooda...' he says:

O, you fool who desires woman
touch her not with eyes, mind or body.

It takes but a minute to fathom this enchantress as enemy.
As lover, she gives you pleasure and denies you eternal salvation.
Destroys the sanctity of your life on earth,
and keeps you in bondage through hundreds of births.

She is the one who begets you as mother,
as wife she destroys you by desire,
taking so many different forms,
Maya incarnate, she throws one into tribulations.[42]

Purandara Dasa goes on to describe how great warriors like Vali, Ravana and Keechaka were destroyed by their infatuation and Indra himself cursed to become impotent by Rishi Gautama because of his seduction of Ahalya. In another song beginning 'Hendati prana hinduti dodda' he sings that the wife squeezes the man and makes him dance like a mountain monkey to her tune.[43]

Similar images of women occur in the writings of the north Indian saints. The fifteenth century saint, Kabir, wrote:

One gold and the other woman,
And into the deepest pits falls man.

Or again:

Kamini (woman), the black cobra, sways the three worlds.

Dadu, Kabir's contemporary, wrote in a similar vein:

Kanak (gold) and Kamini (woman) are verily death, forsake them.
Says Dadu, they burn up the world, like the moth in the flame.[44]

If woman was extolled or praised, it was in her role as virtuous wife. One verse from Tiruvalluvar's *Tirukkural* beginning with the phrase, 'Pennin perundakka yavula' says:

Of all the virtues worthy of woman
the greatest is karpu (chastity).[45]

To quote Kabir in the north Indian context:

The chaste wife, be she dark, ugly or unkempt
hundreds of beauties be sacrificed at her altar.[46]

Again, she was to be revered as the mother. Sivakkiyar, a siddhar, writes:

Ye vetiyar, who recite the Vedas all the time
you who talk of pollution by menstrual blood
know you not that the child itself is made of it?[47]

Nanak, in a lengthy verse says:

Man is born of woman, brought up by woman,
Marries woman, makes her his friend and companion.
If one wife dies, he seeks another, to her he is tied
Why insult her who makes up his very existence?[48]

But is woman to be perceived only in terms of the various roles she performs vis-a-vis man as daughter, wife and mother? Did contemporary society provide any scope for a woman to express her individuality without accepting either marriage or motherhood? A striking verse by saint Dharaanidas (AD 1713) provides an answer:

Forsake the lawful wedded wife who shies away from devotees.
But keep company with that prostitute, who is a true devotee.[49]

The spiritual path helped woman to break out of all stereotypes. As a saint, she made the unacceptable, acceptable. She broke out of the chains of tradition, orthodoxy and convention which sought to control her sexuality and sought God whether as a naked saint (Lalla and Akka Mahadevi) or as a skeletal being (Karaikkal Ammaiyar).

III. THE WOMEN SAINTS

The women saints in medieval Indian society emerged in an atmosphere of discrimination and suppression but blossomed forth into thinkers, scholars and realized souls. Their life and works constituted the supreme form of self-expression of woman. It was an almost violent break away from every traditional role assigned to woman as wife, daughter or mother. Consciously or unconsciously, these women saints made a departure from the norms of social behaviour and spurned the limitations imposed by their families and by society. It is a moot point whether their compositions carried the overtones of protest. Their very emergence in itself was a social revolt.

The life and work of the women saints was shrouded in mystery, unlike that of the men saints. This was partly due to the fact that none of them established a *guruparampara* or monastic tradition with disciples, who might have preserved the sayings or compositions of the saints. The only exception seems to have been Venubai, the disciple of Samartha Ramadasa (seventeenth century) who became the head of the math at Miraj. Rupa Bhavani (or Rwaff), the Kashmiri saint also seems to have had a steady following, although hardly any of her works survive today. Her followers were called Sahib Dhars and they called her Akaleshwari Sahiba. Meera too had a following and the 'Meera Bais' seem to have constituted a minor sect in the medieval period. But very few of the north Indian women saints really gained any recognition for their spiritual greatness during their lifetimes. They were usually scorned by their contemporaries as 'mad' and 'shameless'. Lalla was called *mast* or mad and Meera referred to herself as *diwani,* one who was not in her senses. This was, however, not true of southern India, where the women saints including Akka Mahadevi or the naked saint and Karaikkal Ammaiyar called *peyar* or 'demoness' were greatly revered by their followers as well as peers. Akka Mahadevi was in fact a leading member of the Virasaivite council of saints.

Another factor behind the absence of *sampradaya* or spiritual tradition among women saints was the suppression of their writings by the families of these saints themselves, as in the case of the seventeenth century Kashmiri saint, Roopa Bhavani. In this respect again, the women saints of south India seem to have been more successful because the compositions of Andal, Karaikkal Ammaiyar or Akka Mahadevi and other Saivite and Vaishnavite saints are extant in large numbers. It is possible to explain the differential impact of women saints in north and south India, in terms of the perception of real or imaginary threat to the social fabric in northern India leading to greater rigidity and restrictions on women in contrast to the south. In northern India, the compositions of Meerabai of Rajasthan and Lalleswari of Kashmir have been better preserved than others. The strong musical appeal of these compositions may also have resulted in their being passed down the generations as musical traditions.

The Social Background

An analysis of the social background of these saints reveals some very interesting patterns. Given the great paucity of information in this regard, an effort has been made in the accompanying table to identify the social background of these women saints. For this purpose the area south of the Vindhyas has been divided into two broad zones—north Deccan and south Deccan. Besides tracing the social background of these saints, the effort has also been to point out their Saivite/Vaishnavite affiliations.

The Social Background of Women Saints

	Name	*Period (century)*	*Class*			*Artisanal and labouring group comprising Sudras and untouchables*	*Remarks*
			ruling	*priestly*	*merchant*		
				NORTH DECCAN			
Vaiṣṇavite women saints							
1.	Muktābāi	13th		+			
2.	Janābāi	13th				Śūdra (profession not specified)	
3.	Kanhōpatra					Dēvadāsī (dancing girl)	
4.	Rajāi	13th				Śūdra	Wife and daughter of Nāmadēv, a calico printer
5.	Gonāi	13th					
6.	Mahadamba or Mahadaisa	13th		+			
7.	Soyrabhai	14th				Mahār (untouchable)	Wife and sister of Chokkamēḷa
8.	Nirmala	14th					
9.	Bahinābāi	17th		+			Wife of Kulkarni
10.	Venābāi	17th		+			Child widow
11.	Akkābāi	17th		+			Child widow
12.	Bayābāi	17th					Disciple of Ramadāsa
Viraśaivite (Lingāyat) women saints							
13.	Akkā Mahādēvi	12th			+		
14.	Gangāmbike	12th		+			Related to Basavā
15.	Nilammā	12th		+			Wife of Basavā, author of *Nilammana vacanās, Prasāda Sampadane, and Kalanjana*
16.	Akkā Nāgammā	12th		+			Sister of Basavā, author of *vacanas*
17.	Kalavve	12th				Śūdra-carpenter	Wife of saint Boche Kayakade
18.	Laksammā	12th	+				Wife of saint Kondeyya Manchanna (chief officer of Bijjala)
19.	Mahādēvi	12th	+				Wife of Molige Marayya, vachanā-writer
20.	Lakkhamma	12th				Agricultural landless labour	Wife of saint Ayadakki Marayya

	Name	*Period (century)*	*Class*			*Artisanal and labouring group comprising Sudras and untouchables*	*Remarks*
			ruling	*priestly*	*merchant*		
21.	Kadire Kayakkala Remmave	12th				Spinner by profession (most probably of weaving caste)	
22.	Bontaladevi		+				
23.	Kalavve						Wife of Siddha Buddhayya
24.	Viramma	12th				Jedara —weaving caste	Wife of Dasarayya
25.	Rechchave						Wife of Kata Kuttayya
26.	Guḍḍavve	15th				Chandala	Wife of Battalesvara: lame, but got back her legs by Śiva's grace
27.	Masanamma	16th					Wife of Edemathada Nagidēva
28.	Muktāyi						Sister of yogi Ajaganna
29.	Gōggave						
30.	Lingamma			+			Wife of Hadapada Appana
31.	Nimmavve					Water-carrier	
32.	Vaijakawe						
			SOUTH DECCAN				
33.	Kāraikkāl Ammaiyār	6th			+		One of the Śaivite Nāyanārs
34.	Mangaiyakkarasiyar	7th	+				One of the Śaivite Nāyanārs
35.	Tilakavatiyār	7th				Veḷḷāla – agricultural landowning caste	Śaivite
36.	Tadagai						Vaiṣṇavite
37.	Chankrottuamma	8th					Vaiṣṇavite
38.	Vandi	9th				Roadside hawker	Śaivite saint; her story occurs in Chekkizhar's *Periyapurāṇam* as Pittukku man chumanda Perumān
39.	Aḷagi	11th				Low caste Śūdra (profession not specified)	Śaivite saint
40.	Auvaiyār	12th-13th				Low caste-Anuloma	Śaivite saint daughter of a *pulaya* woman, married to a Brahmin, attained old age by divine grace

	Name	Period (century)	Class			Artisanal and labouring group comprising Sudras and untouchables	Remarks
			ruling	priestly	merchant		
41.	Vāsukiyār	14th				Veḷḷala	Wife of Tiruvaḷḷuvar
42.	Uttiranallūr Naṅgai	15th				Paraiya (shepherdess)	Author of the famous *Paichalur Padikam*
43.	Karūraṁma	17th		+			Vaiṣṇavite
44.	Nanga Peṇṇu	17th		+			Vaiṣṇavite
Vaiṣṇavite saints—disciples and followers of Rāmānuja (based on Jagadeesan 1977: 335)							
45.	Tiruvanantu Purattu ammai	12th					
46.	Tiruvattaṟṟu ammai						
47.	Tiruvaparisarathu ammai	12th					
48.	Maṇṇar Koyil Porreru ammai	12th					
49.	Tirukkanappurattu ammai	12th					
50.	Tirunaraiyūr ammai	12th					
51.	Tirupati srikāryam seyyum ammai	12th					
52.	Āṇḍāḷ ammai	12th		+			Wife of Kurattāzhvar
53.	Nāyaka Dēviyar	12th					
54.	Tuyya Perundeviyar	12th		+			Mother of Gōvinda Embār; also called Diptimati or Periya Pirattiyar
55.	Siriya Āṇḍāḷ	12th		+			Wife of Govinda Embar; in spite of her marital status she was given initiation into *sanyasa asrama* by Rāmānuja
56.	Kantimati or Bhumi piratti	12th		+			Daughter of Sri Saila Purna (mother of Rāmānuja)
57.	Kongil Piraṭṭiyār or Chelanchalamba	11th		+			
58.	Bibi Lachimar	11th		+			Daughter of Muslim ruling chief of Delhi; only Muslim vaiṣṇavite saint; devotee of Lord Rāmapriya of Melkote

	Name	Period (century)	Class			Artisanal and labouring group comprising Sudras and untouchables	Remarks
			ruling	priestly	merchant		
59.	Atuḷai Ammai	11th		+			Daughter of Perianambi, guru of Rāmānuja
60.	Ammangi amma						
61.	Kurattu Āṇḍāḷ						
62.	Dēvaki Pirṭṭiyār						
63.	Yatiraja Vaḷḷiyār						
64.	Pankaja Selviyār						
65.	Ponnachiyār or Hemembāl	12th				Malla (caste of professional wrestlers)	Wife of Pillai Uranga Dāsar
66.	Innila Vanaiyār						
67.	Sudikoduttāl						
68.	Tiruppāvai pādināḷ						
69.	Tripuradēvi	11th				Malla (caste of professional wrestlers)	Wife of Aḳhalanga Nāṭṭalvan
70.	Kumudavalli	11th				Kallar	Wife of Tinumangai Āzhwār (a Kallar); her father was of Vaidya caste
71.	Akkāchchi	12th		+			Wife of Parāsara Bhattar
72.	Manni	12th		+			
73.	Tirumalamma or Tikkamma	14th		+			Wife of Annamācārya: wrote *Subhadra Pariṇayam*
74.	Akkakanna	14th		+			Wife of Annamācārya
75.	Lakṣmi Dēvi or Paratikolla Nachchiyār	12th		+			Wife of Vardācārya Karpasaraṇṇa; fed Rāmānuja and disciples by selling herself to a merchant but the merchant was converted by guru's grace

In this table about 75 women saints have been listed, out of which the social background of 49 has been identified (i.e. 65.33%). Among these 45% belonged to the priestly class, thus constituting the dominant social group. This is closely followed by the professional or artisanal classes (including the shudras and the untouchables) who constitute 41%. The ruling class forming just 10% and the merchant class comprising 4% are both to be seen as peripheral groups in the whole process of the emergence of women saints. One plausible explanation for this is the higher awareness levels of both these groups. While the Brahmin women had some access to education, both sacred and secular, the awareness of the shudra women arose from the fact that, economically, they were almost co-equals with men.

Further, it is interesting to note that of these women saints, 57% were Vaishnavites and 43% were Saivites. It would also appear that the majority of the lower caste saints were associated with the heterodox, sometimes anti-Brahmanical cults of the Bhakti movement.

like Vira Saivism. Although lower caste women saints do occasionally figure in Ramanuja's Srivaishnavism, this was still essentially orthodox in its essence. In spite of some departures in practice, the theoretical norms were still rigid. Excessive liberation was rejected by Ramanuja in his *Sribhashya Subhasutradikarana* and the *Srutaprakasikai.* This view was endorsed by Vedanta Desikar in his *Nyaya Parisuddhi.*[50]

It is, however, interesting that the only instance of initiation into sanyasa ashrama and that too of a married woman (done by Ramanuja himself) occurs in this movement (see number 55 in the Table). Otherwise, by and large, lower class representation in Srivaishnavism occurs in north Deccan in the Maharashtra region.

Although no similar analysis has been attempted for northern India, a preliminary survey of north Indian women saints suggests that here too the same trends may be perceived.

An analysis of the social background of these saints indicated that, since quite a few of them came from the priestly class, they seemed to have had access to religious or spiritual knowledge. This was true of Lalleswari or Lalla and Rupa Bhavani of Kashmir; Muktabai, Bahinabai and Mahadamba (the earliest poetess in Marathi literature who lived in the thirteenth century) of Maharashtra; and among the south Indian saints of Andal Ammai, the only woman Alwar saint, Atulai Ammai, the daughter of Perianambi (Ramanuja's guru), and the saint from Kerala, Karuramma. Even though these women were excluded from the gurukula system, (a point that was made in the first part of this paper), their family background enabled them to gain access to a certain amount of shastraic scriptural knowledge.

At the other end were the low caste women saints. These women, though excluded from scriptural knowledge, could and did have access to knowledge which was based on folk tradition. Their language was not Sanskrit but the local languages. In fact, with the exception of Tamil which goes back into antiquity, the other Dravidian languages took birth during this period - Malayalam in the tenth century, followed by Kannada and Telugu in the twelfth-thirteenth century. This made possible the tremendous contribution of women to vernacular literature. Akkạ Mahadevi's contribution to Kannada literature is paralleled by similar achievements by north Indian saints—Lalla's to Kashmiri, Meera's to Hindi, etc.

Quite often the family had already had examples of renunciation, as in the case of Vishnuchittar, Andal's father who became celebrated as Periyalwar, and Jnaneshwar, the brother of Muktabai. Other examples are Kamali, the daughter of Kabir, and Nanibai and Matabai, the daughters of Dadu. In the case of the Saivite Nayanar saint Tilakavatiyar, she in fact is said to have inspired the spiritual transformation of her brother Marulneekki, who later became known as Appar or Tirunavukkarasar.

In the context of the role played by women saints it is important to note Chekkizhar's comment on the birth of a girl. He said that the wife of Saint Manikkavachagar gave birth to a daughter who would help him to free himself from the cycle of birth and death.[51] There are other favourable references to the birth of daughters in the *Periyapuranam.*

Although both brother and sister of a family may have taken to spirituality, there is a distinct difference in the paths taken by men and women. This is because Hindu scriptures themselves provide the path of renunciation for men in the final *ashrama* or stage—*sanyasa.* It was, however, only the upper castes who were qualified to adopt this course. This spiritual path was closed to men of lower castes as well as to women. Therefore, while Jnaneshwar or Appar would have social sanction for their renunciation, female asceticism was, prima facie, a flouting of existing social conventions.

However, the scope for changing the existing order of things was provided by the medieval Bhakti movement. The Brahmin Periya Nambi performing the funeral rites of Maranar Nambi, an untouchable, and Siriya Andal, the wife of Govinda Embar, being given sanyasa by Ramanuja, are two striking instances. Thus, in an overturning of social conventions, both the women saint and the low caste male saint find a certain degree of acceptability.[52]

Rebels, Conformists and Others

The women saints can be classified into a few broad categories on the basis of their choice of spiritual path and their particular interaction with traditional society. If at one end of the spectrum are the rebels—Meera and Akka Mahadevi—at the other end one can locate the pious and chaste housewives, the ideal stereotype of womanhood like Vasukiyar, wife of Tiruvalluvar; Nilamma and Nagalochana, the wives of Vira Saivite saint Basava; Vishnupriya, wife of Chaitanya; and Bahinabai, wife of Kulkarni. Another example is that of Tilakavatiyar who elevated 'karpu' or chastity to such a height that she began to live as a widow when her betrothed Kalaippagaiyar died in battle. In between these two ends of the spectrum are those women saints who gave up their homes and a conventional style of life only when they were driven to it and were left with no other option. Karaikkal Ammaiyar, Lalleswari and Rupa Bhavani are the best examples in this category.

A.K. Ramanujam[53] has attempted a 'flow chart of possibilities' of the stages of life for women saints. But while his chart categorizes variations in the behaviour patterns of the unconventional saints, it leaves out the conformists like Vasukiyar and other saintly wives who formed a fairly important category. The majority of these women saints were not social rebels in the conventional sense of the term. Quite a few of them seem to have accepted the yoke of marriage as inevitable. Indeed, Vasuki subscribed entirely to the traditional role model of women. It is said that Valluvar wished to test Vasuki before he married her. She had to turn the sand he gave her into cooked rice. This she accomplished by the power of her chastity and Valluvar married her. At another time, spiritual aspirants came to Valluvar to ask him whether the path of the householder or of the ascetic was superior. Just then Valluvar was having a meal of cold rice and he told Vasuki to fan his food which he claimed was piping hot. Vasuki's 'karpu' made steam arise out of cold rice ! While drawing water from the well she was summoned by her husband and as she hastened to his side, the water filled bucket remained suspended in the air. Thus Vasuki demonstrated that marriage to a chaste woman who looked upon her husband as God and obeyed his every command, was superior to leading the life of an ascetic.[54] Bahinabhai writes in very similar vein in her poetic compositions:

> A dutiful wife carries on her household duties and her religious duties simultaneously. A wife must make her domestic life happy by accepting her husband's wishes in a noble spirit, and, though it may mean even death to her, she should not transgress them. Blessed is she, her caste and her family.[55]

This obedience even meant the surrender of one's chastity, as happened with Kabir's wife who was left by him in the house of a merchant (according to another version Kabir never married) or the Nayanar saint Iyarppagaiyar who offered his wife to his guest,[56] in both cases without encountering any opposition from their spouse. Vishnupriya, the wife of Chaitanya, is also classified among the saintly women of Bengal. She was however plunged into a life of austerity and renunciation because even when he married her as a second wife, Chaitanya's domestic life was already over. His only expectation of Vishnupriya was that she should serve his mother well. Similar was the fate of Saint Basava's second wife, Nagalochana, and it is believed that her *vachanas* (spiritual sayings) were in fact the sublimated outpourings of her insatiated desires.[57]

Marital Discord and Renunciation

Lalla and Meera were both reluctant brides. Lalla was married to a Brahmin at the age of twelve and Meera was married to Prince Bhoj Raj of Mewar. The question of Akka

Mahadevi's marriage is shrouded in mystery and controversy resulting from the ambiguity in the medieval sources themselves. While *Prabhulingaleele* of Chamarasa says that Mahadevi went to King Kausika's palace but never married him because he refused to give up Jainism, Harihara, another writer, refers to her marriage with king Kausika and her ultimate renunciation.[58] However, in the case of Akka Mahadevi it is a moot point whether she got married or not. She obviously never led a married life. All sources, however, agree that her renunciation came when she walked out naked from Kausika's palace with her long hair as her only covering.

Lalla, Meera and Rupa Bhavani also walked out of their homes mainly because of domestic ill-treatment. It is said of Lalla that her mother-in-law used to place a stone on her plate covered with a thin layer of food, thus virtually starving her. On the occasion of a function called *Grihashanti* (literally 'for peace in the home'), Lalla's friends teased her about the many excellent dishes she would get to eat, to which she replied with the now famous verse:

> They may kill a big sheep or tender lamb
> Lalla will have her lump of stone all right.[59]

Rupa Bhavani who lived in the seventeenth century was the daughter of a Saivite Brahmin Madhao Dhar. She was married before she was ten and was ill-treated and tortured for dowry. Finally, she walked out of her married home and learnt spiritual discipline under a Sufi, Shah Sadiq Qalandar. Many of Meera's verses abound with references to the ill-treatment by the Rana of Mewar, her mother-in-law and sister-in-law Udhabai:

> The mother-in-law fights, the sister-in-law teases, the Rana is angry,
> They guard me, they spy on me , imprison me with heavy locks.[60]

Akka Mahadevi also refers to ill-treatment in her vachanas, although this is more allegorical than real:

> I have Maya for mother-in-law,
> the world for father-in-law,
> three brothers-in-law like tigers,
> and the husband's thoughts
> are full of laughing women
> no God, this man,
> and I cannot cross my sister-in-law.[61]

Another classic case of marital ill-treatment was that of Chakkubai. She was treated like a chattel and locked up as being insane. She was tied to a pillar so that she would not be able to join the group of saints led by Kabir and Namdev going to Pandarpur.

Ill-treatment in married life was combined with an unnatural husband-and-wife relationship. Lalla believed that her husband was actually her son in a previous birth, though he continued to follow her in the vain hope of bringing her back. Commenting on her unnatural domestic life, Lalla says in one vak: 'I have not been confined nor have I borne a son'.[62]

The incidents in the life of Punitavati (Karaikkal Ammaiyar, one of the Nayanars), are even more bizarre. Her husband feared her spiritual powers to such an extent that he could no longer look upon her as his wife. He disappeared from Karaikkal and settled down in Madurai with another wife. When their mutual well wishers brought Punitavati to him, he fell at her feet with his new family and sought her blessings! In Hindu tradition, wherein it is the wife who serves and worships her husband, there could be no greater reversal of roles.

These women saints did not have the conventional urges of marriage, and home and marriage to them implied duty fulfilment. Therefore, when her husband Paramadatta abandoned all claims upon her, Karaikkal Ammaiyar gave up her beautiful earthly body and assumed a fearful skeletal form.

Brides of the Lord

The third category of women saints consisted of those who never went through a worldly marriage. They included Muktabai and Janabai (Vishnu devotees), Goggave (Lingayat), Andal (Vaishnavite Azhwar), and Nangapennu (Vaishnavite from Kerala). It is interesting to note that, irrespective of whether they were actually married or not, many women saints believed themselves to be brides of the Lord. Meera looked upon Lord Krishna as her husband and put the bridal garland upon him. She sang:

'Giridhar Gopal is my husband, I have no other.' This was not a vague or metaphysical relationship but a physical surrender of oneself, body and soul, to one's divine husband. Akka Mahadevi's verses are strikingly intense in the expression of this love. Before the Lingayat spiritual council, the *Anubhava Mantapa*, she declared:

> The preceptor became the giver;
> The Lord Linga became the bridegroom;
> And I became the bride.
> All this the world knows
> The innumerable devotees are my parents
> Hence Channa Mallikarjuna is my husband, O Prabhu,
> I have nothing to do with the husbands of this world.[63]

Another vachana expresses the same idea in almost violent imagery:

> On a frame of water, raising a roof of fire,
> Spreading the hailstones for the bridal floor-bed,
> A husband without head, married a wife without legs,
> My parents gave me to an inseparable life,
> They married me to Lord Channa Mallikarjuna.[64]

Elsewhere in a verse close to spiritual eroticism, she said:

> He bartered my heart,
> Looted my flesh,
> Claimed as tribute
> My pleasure
> Took over all of me
> I am the woman of love
> For my Lord Mallikarjuna.[65]

Andal, the daughter of Periyazhwar got the name Kodai (garland) since she daily fashioned a garland for the Lord, put it on herself and on Him. Her marriage to Lord Sriranganatha (Vishnu) is described in a series of dreams in her work *Varanamayiram*. The style is less intense than that of Akka Mahadevi:

> The marriage tent is decorated,
> The podium was adorned with garlands of pearls
> The golden poornakumba (auspicious pot) is ready
> I see Madhava enter like a handsome young bull
> In the presence of Gods, he takes my hand,
> And circumambulates the fire
> This dream I saw, my friend.[66]

In her other work, *Nachchiyar Tirumozhi,* she writes:

> How fortunate is the conch which Kannan takes to his lips.
> Andal enquires of it how they taste?
> Does it have a flavour as that of *karpuram* (Camphor)?
> Has it the sweet odour of the lotus ?
> Does it taste sweet, that handsome mouth of coral hue?
> I'm dead earnest to know
> How the mouth of Madhavan, who broke the horn of the tusker
> Tastes and smells, O thou, silvery conch of the sea.[67]

It is said of Andal that she finally merged with the Lord of Srirangam.

One of the most dramatic rejections of marriage was by a saint from Kerala called Nanga Pennu (period not known but could be seventeenth century). She belonged to a Brahmin family of Trippunittura, the seat of the royal house of Cochin. On the day of her marriage, while the bridegroom was being brought to her house in a grand procession, the bride fled the wedding scene and merged in the image of Lord Vishnu in the Tiruppunittura temple. Even today the memory of this event is kept alive by the annual celebration in that temple of the Nanga Pennu festival. One of its most important functions is the procession of the deity as the bridegroom to the paternal home of Nanga Pennu.

It is interesting to note that while the concept of the 'Bride of the Lord' came naturally to women saints, it was not uncommon among the male Bhakti saints to see the *jivatman* (individual soul) and *paramatman* (supreme soul) relationship as a husband and wife relationship. Tirumangai Alwar, a male saint, preferred to adopt femininity and looked upon Krishna as his bridegroom. Manikkavachagar, in his *Tiruvachagam,* says:

> Eternal bridegroom He is
> Paragon of beauty He is
> He resides in me, mother.[68]

The Virasaiva philosophy is in fact based on the principle that the *sarana* or devotee is the bride and the *linga* the bridegroom. The Saiva Siddhanta as well as the siddhar saints used the man-woman relationship to express the God-soul relationship.[69] The 'Bride of the Lord' concept was also found in Kabir and the *ashtachap* saints of northern India.

IV. SEXUAL TRANSCENDENCE AND THE CULT OF DEMONESS

It is only in the spiritual sphere that the common sense view of terms like 'male' and 'female' get turned upside down. Many of the saints believed all creation was the product of *shakti* and the supreme creative power to be feminine. Akka Mahadevi sang:

> I saw the haughty master (Mallikarjuna)
> for whom men, all men,
> are but women, wives.[70]

Another famous incident in this regard comes from the life of Meera. When Meera was stopped from meeting Sant Gosai at Mathura because he did not permit women in his hermitage, she told him, 'I did not know there were any other men here besides Giridhar Gopal', which meant that the only Purusha or male was Paramatman and all creation being maya or illusion, was feminine. The soul itself is neither male nor female. Devara Dasimayya's verse asks:

Was there the breast and the braid in the breath of the wife?
Was there the sacred thread in the breath of the master?[71]

In parallel logic the Sidda poets ask whether anyone can tell if the human breath, the essence of life, is male or female. In some of her vachanas when talking of her state of self-realization, Akka Mahadevi describes herself as male:

A woman though in name,
I am, if you consider well,
The male principle.[72]

Another striking feature of spiritualism among women was their total transcendence over what were normally regarded as feminine virtues like beauty, modesty and gentleness. It is in this light that one should look at the form of Kali or Durga who approximates to the deity Korravai among the Sangam Tamils. Sangam poems state that warriors propitiated the goddess by blood sacrifices, human and animal, accompanied by a weird dance by the priestesses, called *vettuvavari*, in the course of which they predicted what evils might befall the community and how they might be averted.[73] The *Silappadikaram* describes Korravai as 'the three eyed goddess, whose crown is adorned with the crescent moon, whose lips, red as the coral, are parted in a smile, whose waist is encircled by a serpent, whose arm wields the trident and whose feet, bedecked with anklets, rest upon the severed head of Mahishasura'.[74]

The entire cult of the worship of *peymagalir* or demonesses is to be viewed as the antithesis of the feminine image. The *peymagalir* were referred to in the Sangam text *Purananuru* as eating the flesh of the dead and dancing in the cremation ground. The *Purananuru* essentially referred to them in the context of the battlefield as eating the flesh of the enemy. It was argued that the origin of the custom lay in agriculture, in plucking the heads of corn and offering a sacrifice before consuming them.[75] Therefore, a close relationship existed between the mother goddess or fertility goddess and the unusual manifestation of the *peymagalir*. The emergence of the mother goddess must itself have been due to the fact that woman was the primary force behind the earliest agricultural practices.[76]

It is this form of the *pey* or demoness that is taken by Karaikkal Ammaiyar. One of the leading Nayanar saints, Sundarar, said that he was the slave of Peyar Karaikkal Ammaiyar—'Peyarkkum adiyen'. In her composition *Urtvatandavam*, Karaikkal Ammaiyar referred to herself as 'peyar'

With bulging eyes and sunken pit like mouths
Two protruding front teeth and long, lean ankles
A female goblin (meaning herself) has established
itself in the cremation ground of Tiruvalangadu.
Here dances Siva with serenity.[77]

This was the sole theme of her poems on Tiruvalangadu (Tiruvalangadu Moota Padippakam). The saint, transforming herself into a she-devil 'Pey' sings in the first of these poems:

She has shrivelled breasts
and bulging vein,
in place of white teeth
empty cavities gape.
With ruddy hair on her belly
a pair of fangs, knobby ankles and long shins
the demon woman wails
at the desolate cremation ground.
Where our Lord,

> whose hanging matted hair
> blows in all eight directions,
> dances among the flames
> and refreshes his limbs
> His home is Alankadu.[78]

The tantrika cults of Bengal based on shakti worship were very powerful in medieval India, and were again dominated by women and involved practices which were secretive and appeared contrary to all social norms. One of Ramakrishna's gurus was the tantrika Bhairavi. Hemalata who lived in the seventeenth century was a woman saint well versed in tantrika Srivaishnavism. She was a spiritual successor to her father Srinivasa Acharya and seems to have had some disciples. However, no compositions by her exist. Another saint was called Ardhakali because half of her body was dark like that of Kali, the divine mother. Her real name was Jayadurga. A Sanskrit work called *Raghavadipika* written by a contemporary Vishvadeva Acharya gave biographical details of her life but no works by Ardhakali exist.

The Naked Saints

Irrespective of the school of thought she represented, the woman saint unlike her male counterpart was totally free from inhibitions. She recognized neither male nor female nor suffered from body consciousness. Akka Mahadevi went naked with her body covered only by her long luxurious hair. In one of her vachanas, she said:

> To the shameless girl
> wearing Mallikarjuna's light, you fool,
> where is the need for cover and jewel?[79]

An entire discussion by the male saints on the nakedness of Akka Mahadevi took place in the Anubhava Mantapa and was narrated in the virasaivite vachanas. Allamma Prabhu led the attack and asked her:

> Is it true that you laid the blame
> and left him (Kausika) by shedding your dress
> and laying the body bare?
> The error of your mind cannot be stilled
> The garment of your hair yet screens your form.
> How is it your shame is shed?[80]

There are other vachanas which go on in the same strain. Mahadevi's reply was a telling one. She claimed that she covered her body not so much for herself as to save others from temptation:

> Unless the fruit is ripe within,
> the outer peel will never lose
> its gloss... I covered myself
> with this intent
> lest sight of seals of love
> should do you hurt
> Is there any harm in this ?[81]

The best defence of Akka Mahadevi's action, however, came from her guru Basavanna:

> Does the one who has loved
> the one without form
> have need of body?
> Does one who has loved

the one without mind
have need of shame?
Does one who has loved
the sky-clad one
have need of a girdle-cloth?
A devotee like Mahadevi akka
needs no encumbrances at all.[82]

The Kashmiri saint Lalla was again said to have discarded her clothes and danced naked. In her vak Lalla sang:

Lalla, think not of things that are without
Fix upon thy inner self thy thought:
So shall thou be freed from doubt
Dance then Lalla, clad but in the sky
Air and Sky, what garment is more fair,
'Cloth', says custom, does that satisfy?[83]

Lalla danced naked in public and when her father-in-law tried to point out her unbecoming conduct in front of so many men, she was reported to have said: 'I see no men, I see only sheep.' [84]

This shedding of all inhibitions constituted the ultimate act of defiance by these women saints in their flagrant denial of woman's sexuality and their refusal to conform to sexual expectations.

Meera flouted social conventions in her own manner. In spite of being a Rajput queen, who should have been behind strict *purdah* (veil), she danced with anklets on her feet in the motley company of devotees and sang in abandon:

pag gungroo bandh Meera naachi re
(Meera dances with anklets on the feet [85]).

As is well known, anklets and dancing were associated in those times only with courtesans or devadasis. Thus, not only did Meera refuse to wear the veil but she danced in public like a nautch girl. This showed the extent of Meera's defiance. She sang:

I will dance for Giridhar
I care nothing about public shame or family pride.[86]

Breaking Taboos

A third dimension to the breaking of social norms comes from the life of Karuramma, the seventeenth century saint from Kerala. In a startling instance of the breaking of ritual taboo on female pollution during the menstrual cycle, Karuramma entered the sanctum sanctorum and engaged in worship. Her action shocked her contemporary, Vilvamangala Svami, who rebuked her. Karuramma retaliated, 'Can anyone guarantee that one will not die in this state of physical impurity', thus asserting that the right to salvation was more important than the preservation of ritual taboos.[87]

These women saints also left their homes to mingle freely with male saints and scholars. Meera sang 'By keeping company with saints, I have lost the respect of society.' Akka Mahadevi asked:

'Having made one's home in the market place, how
can one afford to shrink from its noise?

Having been born in this world, one should not
lose one's temper at praise or blame ...[88]

In a strong gesture of defiance toward her persecutors, Meera said:

Rana, to me even this shame seems sweet
Let anyone insult, anyone laugh, I walk with firm, unfaltering steps.
When I talk with saints, wicked people rebuke me
but Meera's Lord is Giridhar Gopal, may the wicked
feed the kitchen flames (*angiti*)[89]

Here is sufficient proof that the protest or defiance evidenced by these women was not always unconscious, but was at times quite deliberate, as in this case where Meera confines her detractors to the flames—'angiti'!

Women Saints vis-a-vis the Male Sex

The lives of these women saints shows that the male, including their husbands (with the exception of the Guru) played but a negative role in their lives. A major factor behind conjugal estrangement seemed to have been the miraculous spiritual powers possessed by these women saints and manifested by them unconsciously. Of Lalla it was said that her mother-in-law would poison her son's ears with tales of Lalla's infidelity. In anger, he stoned the pot which Lalla carried on her head, but although the pot broke, the water remained frozen on her head. Her spiritual powers terrified her husband into abandoning all claims over her.

Karaikkal Ammaiyar (Punitavati's) release from family life came about in a similar manner. She was married to a leading merchant from Nagapattinam called Paramadatta, who was an extremely jealous man. He had once given to her two high quality mangoes, one of which Punitavati gave away to a Saivite mendicant. When Paramadatta came for his lunch, he ate the first mango and then asked for the second mango. Out of fear of her husband's wrath, Punitavati materialized the mango spiritually. Finding that its sweetness far exceeded that of any mango he had eaten, Paramadatta became suspicious. He commanded her to materialize one more mango, but while this appeared in her hand it vanished the moment he touched it. The incident was one of terrifying realization of his wife's powers for Paramadatta, who abandoned Punitavati and married another woman. Rid of worldly obligations, Karaikkal Ammaiyar is said to have assumed a skeletal form and renounced home.

However, miracles were not always a manifestation of conjugal estrangement, but quite often of conjugal harmony resulting from the woman saint conforming to the traditional role model. Besides the incidents quoted from the life of Vasukiyar, many of the miracles in the lives of the Vaishnavite women saints bear testimony to this. There is for instance, the story of the virtuous wife of saint Varadacharya, Lakshmi Devi, also known as Paratikolla Nachchiyar. When Ramanuja and his disciples were once journeying through their town, they were turned away from the door of a rich man and so came to the humble abode of Varadacharya seeking his hospitality. The saint was away at the time and Paratikolla Nachchiyar found the stores at home empty. Hence she sold herself to a merchant for provisions and fed the devotees. Hearing the nature of the promise, Ramanuja gave her holy water which converted the merchant as soon as he partook of it.

There was similarly the incident in the life of Andal, the wife of Kurattazhwar, who happened to remark one stormy night (when her husband could not go out for alms) that the Lord was feasting sumptuously while his devotees starved, and immediately a delicious feast materialized before them.

V. ALIENATION AND POETIC IMAGINATION

The compositions of these women saints undoubtedly depict the mood of freedom from material things and the achievement of spiritual bliss, but they also portray their alienation from society and personal loneliness. On being asked by the Chola king (probably Kulottunga, thirteenth century) as to where she came from, the Tamil saint Auvaiyar replied:

> My legs are aching, paining
> Fast have I walked
> and weary distance journeyed...
> What place shall I call my own?
> A wanderer like me.[90]

This alienation of the women saints was a dual-alienation: first, because they were out of tune with the world and material pursuits and, second, there was the social alienation resulting from their being non-conforming women. Akka Mahadevi wrote:

> Like a silkworm weaving her house with love.
> from her marrow, and dying in her body's threads,
> winding tight, round and round, I burn
> desiring what the heart desires, O, Mallikarjuna.[91]

Meera similarly described herself as a fish out of water, a chakravaha bird deprived of the sight of the beloved, a lonely and lost soul.

Powerful Imageries

Some of the women saints used very powerful imagery in their compositions. This was true of all the compositions of Karaikkal Ammaiyar like 'Urthva Tandavam', 'Arpuda Tiruvantadi' and other poems in the eleventh book of *Tirumurai*, the Saivite canonical works. They were a brilliant portrayal of the cosmic dance of Siva. Some unusual and mystic imageries can be found in the poetic compositions of a fifteenth century woman saint of Tamilnadu, who is not known by her proper name but as the maiden (*nangai*) of Uttiranallur. In her *Paichalur Padikam* she writes:

> I have seen the tuft on cock, the tattoo on hen
> So have I seen the fire on water
> Citing your satkula, speak not to me of four Vedas
> Use your discretion to see truth, ye elders of Paichalur.
>
> Village Brahmins gather, build a high wall (the sacrificial vedi)
> Dip in the river and pour clarified butter on fire
> Like frogs in the rains, they croak the Vedas
> Have they gained salvation ye elders of Paichalur?[92]

Janabai at times uses an abusive form of adoration:

> Vithya, Vithya, Thou art the spoilt child of the primeval maya.
> Thy wife has become a courtesan, thy body is dead.
> Janabai stands in the courtyard of her house
> and abuses Thee left and right.[93]

However, the most unusual or startling imageries are to be found in the *abhangs* (hymns) of Muktabai, the sister of Jnanadev. Of her state of realization she says:

> I saw an ant float in the sky,
> The ant devoured the sun.

A great wonder it was that
A barren woman gave birth to a child.
A scorpion went to the nether world
And the serpent fell at its feet.
A fly was delivered
And gave birth to a kite.
At these experiences Muktabai laughed.[94]

To Changadeva, one of her principal followers, she said that he should speak words of silence (*abhang* 9), sleep the sleep of ecstasy wherein the unstruck sound is heard (*abhang* 10). 'In that state', says Muktabai, 'the bridegroom will come from the womb of the bride, and as the bridegroom comes out, the bride will vanish from before him and there will be no limit to the happiness that may be enjoyed' (*abhang* 12).[95]

The only parallel with the mystic imagery of Muktabai are the *ulat sawayyan* or the inverted truths found in Kabir's poetry, such as the tree with its roots outside and the branches beneath the earth and the upside down well,

Along with the male saints of the Bhakti movement the compositions of the women saints marked a substantial contribution to the growth of vernacular literature, like Lalla's to Kashmiri, Akka Mahadevi's to Kannada and Meera's to Hindi.

Linkages between Everyday Crafts and Religion

The close association between the weaving loom and the poet saint Kabir is illustrated in his composition 'Jhini jhini beeni chadariya'. While such an obvious link is not always to be perceived, especially in the writings of those women saints who were housewives, the connection between one's profession and one's spiritual ideology was evident in the case of the Virasaivite women. The spinning wheel, for instance, was a recurrent metaphor in the vachanas (poems) of Remmavve, who was a spinner by profession. She writes:

Fast turning spinning wheel
Listen to the caste and lineage (*kula jati*)
of the spinning wheel I turn.
The plank below is Brahma.
The torana (decoration) is Vishnu.
The wooden idol (bobbin winder) is Maha Rudra
The two threads that pass through constitute intellect
Awareness is the spindle
You turn the wheel by the handle called devotion
the threads turn and the bobbin is filled.
I cannot turn the spinning wheel
because my husband has beaten me.
What can be done
Lord Gummisvara.[96]

It is noteworthy that in medieval Kannada literature she is always referred to as Kadire Remmavve, 'Kadire' meaning 'spinning'. In fact the names of many of the Virasaivite (lingayat) women saints was prefixed by their profession, like Kottanada (grain pounder) Somamma and Ayidakki (rice cleaner) Lakkhamma. Everyday technology and everyday occupations like grinding and pounding, rice cleaning and pot making occur frequently in the writings of Virasaivite women saints. Somamma writes:

If you pound grain
missing your step

being over-crushed
the grain is no longer edible.

Association with apostates.
results in hell, not salvation![97]

Ketala Devi, a potter, uses the metaphor of the pot for the human body. In one vachana she writes:

If that particular clay is not there
It is impossible to make the pot.
If you mix(with apostates)
hell is sure
knowing all this one should not mix
O, Kumbesvara![98]

What is most striking about this verse is that Ketala Devi addresses Siva himself as 'Kumbesvara' meaning 'the great potter'.

The linkages between traditional crafts, technology and popular religion is even more striking in the case of Sufi folk literature. In folk music genre called 'Charkha Nama' and 'Chakki Nama', women sang devotional songs to the rhythm of spinning and grinding, both of which were women's occupations. In an interesting article 'Sufi Folk Literature and the Expansion of Islam'[99] Richard Eaton has shown how the composers as well as the disseminators of these Sufi songs were women. Indeed, these compositions were in Deccani, a conflation of Urdu and Telugu. Eaton writes that he even came across a 'Chakki Nama' in the Kannada script.

I reproduce here two compositions from the 'Charkha Nama' detailed in Easton's article:

Imagine that your body is a spinning wheel, oh sister
We should get rid of our negligence
and give up worldly differences, oh sister.

The tongue is the unspun thread for the message of God;
The tongue is the rim of the spinning wheel.
Bring out the thread of breath and show it, oh sister.
Both of these memories should be in our throat:
God has given us the ability to turn our hand
and it is that which moves the wheel, oh sister
Faith must be for you what the drive-rope is for the wheel.
Perhaps you know of the two wheels connected by the rope;
Then you will know how the wheel turns, oh sister.

In another 'Charkha Nama' the principle of Sufi Zikr (spiritual exercises for a Sufi) was illustrated in the context of the everyday technology of spinning:

As you take the cotton you should do Zikr-i-jali
as you separate the cotton you should do Zikr-i-qalbi
And as you spool the thread you should do Zikr-i-aini
Zikr should be uttered from the stomach through the chest
and threaded through the throat
The threads of breath should be counted one by one, oh sister
upto twenty-four thousand
Do this day and night
and offer this to your Pir as a gift.

These verses show the mingling of high and low Sufi traditions. Esoteric Sufi philosophy was adapted to household women's activities, like spinning and grinding. The Sufi 'Charkha Nama' and 'Chakki Nama' were therefore akin to the abhangs of Janabai or the vachanas of the Virasaivite women saints.

VI. SOCIAL IMPACT OF WOMEN SAINTS

The emergence, life and creative works of these women saints thus had a significant impact on contemporary society. Their contributions were both direct and conscious as well as indirect and unconscious. The role played by the Nayanar saints Mangaiyarkkarasiyar and Tilakavatiyar in the restoration of Saivism in the face of the growing challenge from Jainism was a direct and conscious one. Mangaiyarkkarasiyar's husband, the Pandyan king (seventh century AD), was a Jain and this also appeared to be the common religion of the land. With the aid of her famous contemporary saint Tirujnanasambandar, Mangaiyarkkarasiyar succeeded in restoring Saivism in the land. In his *padikam* starting with the word 'Mangaiyarkkarasi' the saint Alway called her 'the Pandiyan queen who is devoted to the cause of Saivism'. The compiler of *Periyapuranam*, Chekkizhar, called her 'the divine maiden who avenged the honour of the South (Thenkulam,) removed the obstacles in the path of Tamil and spread the message of Saivism.'[100]

Tilakavatiyar, who also lived in the same century, saved her brother Marulneekki from the clutches of Jainism. He had in fact become the head of a Jain monastery under the name Dharmasena and it was when she cured him of a deadly disease through the demonstration of her spiritual powers that he came back to the fold of Hinduism. This was acknowledged by him in one of his *padikams* starting with the word,'Kutrayinavaru'[101] in which he said:

Losing the protection of her who was my guide
I fell into the pit from which I had no redemption.

He later became renowned as Appar or Tirunavukkarasar.

Rejection of the Caste System

The representation of social protest in the lives and works of these women saints was, however, much more subtle and less conscious except in the case of Auvaiyar from the south or Rupa Bhavani from Kashmir, who functioned more like social reformers. By and large, the compositions of women saints represented the intense personal search for God in the midst of wholly uncongenial familial and social circumstances. Their comments on the overall social situation were therefore mostly indirect. The portrayal of the highly restrictive life of a Rajput woman gathered from Meera's compositions was due more to her autobiographical references than to her observations on contemporary society, which were almost nil. Even her rejection of caste could be understood only through her acceptance of the untouchable Raidas as her guru. Although Bahinabai seemed so conforming and talked about duty fulfilment in her verses, despite being a Brahmin, she accepted the low caste Tukaram as her guru.

As with the male saints of the Bhakti movement there was usually no overt effort to critically examine or overturn the existing social order. In the majority of cases the overtones of protest were found not so much in their role perceptions as in the very fact of their emergence.[102]

Some south Indian saints provided more concrete examples of the rejection of the existing social structure and behavioural modes. Akka Mahadevi says of herself:

O brothers, why do you talk to me
who has given up her caste and sex
having united with Chenna Mallikarjuna.[103]

The maiden of Uttiranallur, although a paraiya by caste, mastered the Vedas from a Brahmin boy and married him. When the elders of the Paichalur village came to the Paraiya street with burning sticks, she responded with her famous *Paichalur Padikam.*[104] Her verses, which I have translated from Tamil, deserve detailed citation because they constitute virulent anti-caste statements:

All your talk of caste and creed
Is it even as natural as the spider and its web?
The four blessed Vedas, were they created by Brahma?
Is caste and creed worthwhile, ye elders of Paichalur?

One palm tree, from it hangs nongu(fruit) and toddy
For the knower of truth one no different from the other
Will one then be superior and the other inferior
Why then blame the paraiya, ye elders of Paichalur?

The smells of neem and sandalwood are distinct when they burn.
But indistinguishable is the smell of the burning Brahmin.
Does fire smell different if an unkempt Pulaya burns?
Does the burning stuff and flame differ, ye elders of Paichalur?

Janabai, herself a low caste, sang in an *abhang* that Chokkamela (a famous male saint, Mahar by caste) was an outcast but had great devotion in his heart and so God became his servant and used to dine with him. Janabai was inclined to laugh because Chokkamela made even God an outcaste like him.[105] The significance of this lies in the fact that upper castes do not inter-dine with lower castes because this results in physical pollution. So, in a logical turning of tables, Janabai inverts the paradigm by making God himself subject to pollution. Soyrabai, the wife of Chokkamela, was a composer in her own right and about sixty-two of her compositions in the form of blank verses have survived. In one of them she says:

The body only can be impure or polluted
The soul is ever clean pure knowledge
The body is born unclean and so
How can anyone be pure in body?
But the body pollution remains in the body
The soul is untouched by it.[106]

A significant example of the breaking of caste taboos comes from the life of Athuloi, the daughter of Periyanambi, the guru of Ramanuja (eleventh century). Periyanambi was ostracized because he nursed and eventually performed the funeral rites of Maranar, an untouchable and his co-disciple. Athuloi stopped the chariot procession of the Srirangams deity and compelled God Himself to bear witness to the righteousness of his action and lift the ban on Periyanambi.[107]

The most pungent commentary on the caste system comes from Auvaiyar (the one who was the contemporary of Kambar and Ottakkuttar in the twelfth century):

There are no castes but two if you want me to tell
The good men who help the poor in distress
The other, that will not so help
These are the low born.[108]

The rejection of caste was of course a recurrent theme with most of the male low caste saints like Kabir, Dadu and Raidas and occasionally even with upper caste ones like Chaitanya.

Strong condemnation of rituals, ceremonies and idol worship come from both south Indian and north Indian saints. Uttiranallur Nangai says:

> The revealed Vedas are lies, body and soul are lies
> Are not all castes one? Is everything variegated?[109]

Lalla says in her vak:

> The idol is but stone, the temple is but stone.[110]

Auvaiyar, more than any other woman saint, has made the most pithy and effective comments about many aspects of early medieval society. She condemned begging and prostitution as shameful and degrading. She warned the parasites at court that royal favour was treacherous and unpredictable while the 'tiller of the soil lives the noblest life.'[111] Although Auvaiyar's genius gave her access to the Chola court, she spent much of her time among the poor. One famous story about this saint has it that once a dancing girl called Chilambi gave 500 gold coins to Kambar to compose a verse on her. He composed only two lines because he felt the payment was inadequate. Auvaiyar came along and seeing Chilambi's distress, completed the stanza accepting in return only a cup of rice gruel called *koozh*. Hence she is also called 'Koozhukkuppadi' or one who sang for gruel.[112]

Religious Reconciliation

It is interesting that like Kabir, Lalla is now revered equally by both Hindus and Muslims. In her life time, she is said to have been the disciple of a priest named Srikanta and the companion of such Muslim dervishes as Sayyid Ali Hamadani and Sayyid Hussain Simnani. In fact Muslim chroniclers like Pir Ghulam Hasan call her Lalla Arifa and say that she was a *rabia* or saint.

Religious syncretism and the creation of a composite culture has been a lasting legacy of the devotional movements of medieval India. The Rishi movement in Kashmir can be regarded as an example of such syncretism. The movement was started in the fourteenth century by Nuruddin Rishi and lasted till the seventeenth century. Lal Ded, the Saivite woman mystic of the same century was closely associated with Nuruddin as well as Sufi mystic Sayyid Hussain Simnani who was his preceptor. It has even been argued by some historians that it was in fact Lal Ded who was the inspirational force behind the Rishi movement. Her place within the movement is a true indicator of its syncretic character. Lalla or Lal Ded is called a *yogini* of the Saivite (*Trika*) tradition as well as 'Maryam-i-Makani' and 'Rabia Thani' within the Sufi tradition. Nuruddin composed the following verse in honour of Lal Ded:

> That Lalla of Padmanpore
> who had drunk to her fill the nectar
> She was an avatar of ours
> O God, grant me the same power.[113]

A recent book by Muhammad Ishaq Khan[114] discusses the Rishi movement and the role of women Shaivite Sufis like Lal Ded within it. Besides Lal Ded the two Hindu sisters Behat Bibi and Dehat Bibi were also converted disciples of Nuruddin Rishi. They were the daughters of a Brahmin Patwari but well conversant with Persian. Another woman Sufi Shanga Bibi had been a courtesan who was elevated to discipleship by Nuruddin. Sham Ded, Sanga Bibi and Ganga Bibi who popularized the concepts of Nuruddin continued to retain their Hindu names and origins.

While the Rishi movement provides outstanding examples of Hindu women Sufis, there are also parallel evidences from the region of the north Deccan, especially Bijapur. Richard Eaton in his path breaking book[115] deals with this phenomenon. He points out that the Hindu-Muslim confluence had always been strongest in this region with the Sultan Ali Adil Shah calling himself Adil Shah Sufi. I have already referred to the traditions of the Chakki Nama and the Charkha Nama in the Deccani language. The dargahs of the Sufis were dominated by women. To quote Eaton: 'Folk Islam in Bijapur as elsewhere seems to have been a female oriented Islam: what the mosque, the mulla and the Koran were for men, the dargah, the pirzada and the Chakki Nama were for women.'[116]

The chief disciples of Hashim Pir Alawi, the seventeenth century Sufi, were women, and the female family members of the celebrated Sufi Gesudaraz at Gulbarga, like his mother and sister, were worshipped by the local people. However, these Sufi women saints were by and large anonymous. One such Sufi woman writes in her Charkha Nama:

> See that our body is also a chakki
> And be careful in grinding
> The devil is my Saukan (co-wife)
> which prevents me from working and tires me
> Ya bism Allah, hu hu Allah.
> The Chakki's handle resembles alif, which means Allah
> And the axle is Muhammad, and is fixed there.
> In this way the truth-seeker sees the relationship.
> Ya bism Allah, hu hu Allah.
> We put the grains in the Chakki
> To which our hands are witnesses.
> The Chakki or the body is in order
> when you follow the Shariat.
> Ya Allah, hu hu Allah
>
> Grind the flour and make stuffed puri;
> put in it heavenly fruits and sugar.
> The seven qualities of God must be taken in the body
> As the seven ingredients fill the puri, oh sister.
> Ya Allah, hu hu Allah.[117]

It is interesting and heartening to note that even today north Deccan retains its composite culture and the syncretic character of its religion. Sufi shrines are revered by Hindus and Muslims alike.

Summing Up

It is doubtful if women saints, with some exceptions like Meera or Lalla in the north or Andal and Auvaiyar in the south, had a major impact while they lived. During their lifetime, most of them including Meera and Lalla were scorned by society as mad and shameless. Thus, medieval social prejudices prevented these women from being taken seriously by the upper echelons of society. Their audience impact was restricted to some low caste workers and artisans and their wives. A recent article has sought to analyse the audience impact of Meera in Rajasthan, and it comes up with the interesting finding that even now in Rajput homes, especially in Sisodiya villages, Meera is considered a taboo. 'But the singing of Meera becomes a political act when it is sung... by the subordinate sections, of peasant and artisan origin who understand that to sing Meera is to flout ruling Rajput authority'.[118] Secondly, the majority of women saints (with a few rare exceptions) left behind no organization (*panth*) and had no steady following which may have helped in the spread of their message.

Where do these women saints figure in the saintly pantheon of Hinduism within the accepted religious framework? The acceptance of Andal and Auvaiyar was found to be easier than the acceptance of rebels like Lalla and Akka Mahadevi. Auvaiyar got around the whole social problem of women's sexuality and moral controls by achieving instant old age by enacting a miracle. The name Auvai itself indicates a wise old woman and in this capacity she commanded great respect. Andal was unconventional in her thoughts and behaviour but did not openly flout any social rules except for opting to remain single, and in this respect she had the support of her saintly father Periyalwar.

It is the saints who flouted every conventional social norm like Lalla and Akka Mahadevi who were made to stand outside the orthodox religious framework. Strangely, in modern India the rebel saints are by and large worshipped with as much acceptance and reverence as the conformists. This may be the result of subtle efforts by the religious orthodoxy to institutionalize them so that their radicalism is neutralized and does not appear as an alternative to the existing orthodoxy. But besides this, the overwhelming historical and structural changes in Indian society have also altered orthodox or conservative attitudes. The mass impact and tremendous social appeal, both among men and women, of the modern woman saint, the so-called 'mataji' or 'guruma', and the enormous growth in the numbers of these saints, is an indisputable proof of this.

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and the Kaikkolar. There is plenty of inscriptional evidence to indicate that many of these Devaradiyar (devadasis), were economically well off.

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18. *ARE,* 141 of 1898; *Epigraphica Carnatica,* IV, HG. 18; *Epigraphica Indica,* VI, pp. 213-19.
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21. Major, R.H., ed. *India in the Fifteenth Century,* 'The Travels of Nicolo de Conti', Hakluyt Society, London, Reprint, New Delhi, Cosmos publishers, 1974, p. 6.
22. *Ibid.* 'Abdur Razzaq's Account of His Indian Travels', p. 17.
23. *Kasikhandamu* of Srinatha cited in K. Satyanarayana, *op. cit.,* p. 138.
24. Hart, George L., *op. cit.,* p. 103, see also *Purananuru,* poems 25, 250, 261 and 280.
25. Ramachandra Rao ed., *Purandra Sahitya Darshana,* 4 vols. Directorate of Kannada & Culture, Govt. of Karnataka, Bangalore, 1985, vol. III, Samaja Darshana, song no. 104, p. 194-5. I am grateful to Mr. Samagana Raju of Delhi Kannada School for helping me with the translation of this and other Kannada songs of Purandara Dasa.
26. *Rukmangada Charitramu* of Mallanna cited in K. Satyanarayana, *op. cit.,* p. 138.
27. Jagadeesan, N., *History of Sri Vaishnavism,* post-Ramanuja, Koodal, Madurai, 1977, p. 195.
28. Altekar, A.S., *The Position of Women in Hindu Civilization,* Motilal Banarsidas, Delhi, 1956, pp. 237-8.
29. *Mitakshara,* the commentary of Vijnanesvara on the *smriti* of Yajnavalkya tr. J.R. Gharpure, Tarporewala, Bombay, 1936-42, vol. I, verse 15.
30. A general discussion on the property rights of women including the *mitakshar's* emphasis on the widow's right to inherit property is to be found in P.V. Kane, *History of Dharmashastras,* Government Oriental Series, class no. 6. Bhandarkar Oriental Research Institute, Poona, 1973 (2nd edition). See specifically, vol. III, pp. 700-49 ff.
31. *The Mitakshara, op.cit.,* ch. II, p. 135.
32. Nagasamy, R., 'A 13th Century Sale Deed On Rights of Women' in his collection of essays called *Studies in Ancient Tamil Law and Society,* Institute of Epigraphy, State Department of Archaeology, Govt. of Tamil Nadu, 1978, pp. 84-8.
33. *Saraswativilasa,* ed. and tr. Rev. Thomas Foulks, London, 1881, p. 13, verse 68 and p. 24, verse117, cited in K. Satyanarayana, *A Study of the History and Culture of the Andhras,* vol. II, *op. cit.,* p. 252.
34. Refer Vijaya Ramaswamy, 'Aspects of Women and Work in Early South India', *Indian Economic and Social History Review, (IESHR),* vol. XXVI, no. I, 1989.
35. The Tamil text of this folk song is to be found in K.V. Jagannathan, ed., *Yetrapadalgalum tozhilpadalgalum,* Kalaimagal, Madras, 1983, pp.15-16. The translation is mine.
36. See Vijaya Ramaswamy, 'Aspects of Women and Work', *op. cit.,* pp. 85-6. It is interesting that this term corresponds closely to the English word 'spinster'. Since a single woman had no one to support her she often had to spin for a living and thus the word spinster came to mean an unmarried woman.
37. This folk tradition is cited in K. Gandhi, *Tamizh Pazhkka Vazhakkangalum Nambikkaigalum,* International Institute of Tamil Studies, Madras, 1980, p. 102, fn. 332. The translation is mine. My north Indian friends tell me that this practice is also prevalent in parts of rural north India.
38. The song has been cited in P. Arunachalam, *Bhakti Ilakkiyam,* Pari Book House, Madras, 1973, p. 102. Some other songs in the same vein are quoted on pp. 246-7 ff.
39. *Ibid.,* p. 103: 'venil vel malarkkanikkum vennagai chevvay kariya panalar'.
40. The lines are from the stanza in the 'Kandar Anubhuti' of Arunagirinathar beginning 'koorvel vizhi mangaiyar...' The translation is mine.
41. Song 1033 translated by V.A. Devasenapati, 'The Philosophy of Arunagirinathar' in *Institute of Traditional Cultures Bulletin,* Madras, 1975, p. 140.
42. *Purandara Sahitya Darshana, op. cit.,* song no.102, pp. 192-3.
43. *Ibid.,* song no.103. pp. 193. The translations are mine.
44. The above verses from the Hindu saints have been quoted in Vimal Mehta, *Nirgun Kaviyon Ke Samajik Adarsh,* Asha Prakashan, New Delhi, 1979, p. 200. The translations are mine.

45. *Valluvar Vachagam,* ed. C.R. Rajagopalachari, Bharati Publishers, Madras, 1960,p.17. My translation. Pages 15-20 contain more verses by Valluvar on wifely virtues.
46. The verse from Kabir has been quoted in Vimal Mehta's book, *op. cit.*, p. 202. The tranlation is mine.
47. The verse has been cited in K.R. Hanumanthan, *Untouchability,* Koodal Publishers, Madurai, 1979,p.173.
48. Mehta, Vimal, *op.cit,* 203. The translation is mine.
49. *Ibid.*, p. 203. The translation is mine.
50. This point has been made by N. Jagadeesan, *History of Srivaishnavism, op. cit.*, p. 334. The list of Srivaishnavite women devotees in the south Deccan given in the above table is largely based on the list provided by Jagadeesan on p. 335.
51. Saraswati, M.E., 'Women in Periyapuranam', *Institute of Traditional Cultures,* Madras, 1975, p.212.
52. 'Bhakti Reversals of Normative Hindu Patterns' in A.K. Ramanujam, 'On Women Saints', J.S. Hawley and B.M. Wulff eds., *The Divine Consort , Radha and the Goddesses of India,* University of California, Berkeley, 1988, Table 3, p. 317.
53. *Ibid.*, Table 4, p. 318-19.
54. Based on the life of Vasukiyar as given in *Arul Mangaiyar Ezhuvar* by C. Swaminathan, Amuda Nilayam Ltd., Madras, 1968, pp. 8-20.
55. These verses of Bahinabai have been cited and translated in 'Bahinabai' by Piroj Anandkar in Swami Ghanananda and Sir John Stewart Wallace ed., *Women Saints of East and West,* Vedanta Press, Hollywood, California, 1979 (first edition, London, 1955), pp.71-2.
56. Saraswati, M.E., 'Women in Periyapuanam' *op. cit.*, p. 216.
57. An amazing controversy has developed in recent years regarding the two marriages of Basava. A Kannada historian M.M. Kulburgi in his book *Marga Ondu,* wrote that Basava's second wife Nagalochane's vachanas expressed her insatiated desires rather than her spiritual experiences. This has stirred up a hornet's nest with death threats to Kulburgi being issued by the Lingayat fundamentalists. It is their belief that the marriage was a purely spiritual union. See 'Rushdie Like Dispute in Karnataka', *India Abroad,* vol. XIX, no. 30, 28 April, 1989; *India West,* 21 April, 1989, also the local Indian dailies.
58. For the outlining of this controversy see 'Akka Mahadevi' by T.N. Sreekantaiah in *Women Saints East and West, op. cit,* p. 35. For versions of this controversy refer H.T. Tipperudrasvami, *Soul Unto the Sublime,* Sri Jagadguru Gangadhara Dharma Pracharaka Mandala, Hubli, 1982 and S.S. Bhoosnurmath and Armando Menezes eds. and tr. *Sunyasampadane,* Karnataka University, Dharwar, 1970, pp. 261-7.
59. Kaul, Jayalal, *Lal Ded* (Lalla), New Delhi Sahitya Academy, 1973, p. 10.
60. Chaturvedi Parashuram, *Meerabai Ki Padavali,* Prayag, Hindi Sahitya Sammelan, 1955-56, p. 113. The translation is mine.
61. The *vachanas* of Akka Mahadevi in A.K. Ramanujam, ed. *Speaking of Siva,* Penguin, London, 1973, p. 114, vachana no. 140.
62. Kaul, Jayalal, *op. cit.*, p. 11.
63. Tipperudraswami, H.T., *op. cit.*, p. 195.
64. *Ibid.*, pp. 223-4.
65. Ramanujam, A.K., *op. cit.*, p. 125.
66. Srivatsan, K. ed., *Nalayira Divyaprabhandam,* Madras, 1984, p. 207, lines 556-65 from *Varanamayiram.* The translation is mine.
67. *Nachchiyar Tirumozhri* of Andal, VII: 1:23, has been cited and translated by K.C. Kamaliah, in 'Women Saints of Tamil Nadu', *Indian Literrature,* 1977, no. 2, p. 59.
68. *Tiruvachagam Annaipattu*-3 of Manikkavachagar, quoted and translated by K.C. Kamaliah, *op. cit,* p. 56.
69. For elucidation on this aspect see K. Kailasapathy, 'The Writings of Tamil Siddhas', in Schomer Karen and Mcleod W.H. ed., *The Sants: Studies in a Devotional Tradition of India,* Motilal Banarasidas, Delhi, 1987, pp. 396-7.
70. Ramanujam, A.K. , *op. cit.*, p. 120; Armando Menezes and S.M. Angadi, *op. cit,* vachana no. 151. Vachanas 149 and 150 are also on the same theme.
71. Tipperudraswami, H.T., *op. cit,* p. 209.
72. Bhoosnurmath, S.S. and Armando Menezes, ed. and tr. *Sunyasampadane,* vol. IV. *op. cit.*, p. 320, vachana no. 44.

73. Venkataraman, K.R., 'Sakti Cult in South India, in *Cultural Heritage of India,* Sri Ramakrishna Centenary Committee, Belur Math, Calcutta, 1936, vol. IV, p. 252.
74. *Ibid.,* cited in K.R. Venkataraman, p. 252.
75. See George L. Hart, *The Poems of Ancient Tamils, op. cit.* pp. 33-4 ff for parallels between the ritual of war sacrifices and crop harvesting.
76. An analysis of the 'peymagalir' and their link to the mother goddess cult is to be found in K. Kailasapathi, *Pandai Tamizhar Vazhvum Vazhipadum,* Pari Nilayam, Madras, 1966, pp. 66-84.
77. Kamaliah, K.C. , *op. cit.,* p. 50.
78. The translated version is from Norman J. Cutler, *Songs of Experience—The Poetics of Tamil Devotion,* Indiana University Press, 1987, p. 121.
79. Ramanujam, A.K., *op. cit.,* 'Speaking of Siva', p. 129.
80. Bhoosnurmath, S.S. and Armando Menezes, ed. and tr. *Sunyasampadane,* vol. IV, p. 297, vacnana no.15 of Allamma Prabhu.
81. *Ibid.,* p. 298, Akka Mahadevi's vachana no. 18.
82. *Ibid.,* p. 271, Basavas's vachana, no.9.
83. Bazaz, Prem Nath, *Daughters of the Vitasta,* New Delhi, Pamposh Publications, 1959, p. 133.
84. Kaul, Jyalal, *Lal Ded, op. cit.,* p. 15.
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104. 'Paichalur Padikam', of Uttiranallur Mangai. The Tamil text is in M. Arunachalam, *Tamizh Ilakkiya Varalaru, op. cit.* pp. 361-2.
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111. Rajagopalachari, C., *Auvaiyar, op. cit.,* p. 12, stanza 21.
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CHAPTER XVI

Science and Social Movements: Bhakti and Sufi Movements

A. Rahman

I. INTRODUCTION

A cursory look at the development of science in different cultures in different periods of history reveals an intriguing phenomenon: when science reaches a high level of development in a culture, different social forces emerge to marginalize it. In other words, other intellectual and social activities come to dominate society, in place of scientific activity. It happened in ancient Babylon, Egypt, India, Greece and in the medieval Islamic culture. This phenomenon requires a detailed and critical study. The studies which have been carried out so far focus attention on the decline of science alone. Indeed, there is no decline at all; what actually happens is that, having reached a certain stage, scientific activity continues at that level in a particular society, while in another society it develops with a new framework.

For the study of this phenomenon, and to have some understanding as to why it happens, three dimensions of human activity require study: (a) human relation with nature; (b) human relation with other humans; and finally (c) looking inward into one's own self. Science plays a major role in the first dimension—that is, man's relationship with nature; and to a lesser extent in the other two dimensions, because here social and biological instincts play a more active role in guiding human behaviour. No doubt, humans may be guided by science, but they also have feelings and emotions, hopes and aspirations, love and affection, and values like compassion, justice and charity. Science with its logic and philosophy and quantitative data does not take these human aspects into account. The neglect of these in a scientific ethos marginalizes human beings, and they react to it and assert themselves to give a new ethos to human society, relegating scientific activity to the sidelines.

Science in Contemporary Society

The dominance of science in contemporary society, both in personal and social lifestyles, the institutions created to promote it, and the resources required by it have also created a reaction, against the method of science, its philosophy, and the emphasis on research for creating weapons of destruction. Further, the primacy given to scientific and technological research has to an extent, marginalized human needs.

These developments in the contemporary period have created doubts about scientific pursuits, putting the neat picture of science under a cloud. Moreover, the implicit philosophy and framework of science, created by the Industrial Revolution and French Enlightenment, is being questioned. The close association of science and technology with the armament industry and commercial interests is being increasingly attacked. The deleterious effects of industrialization on environment and ecology and the depletion of non-renewable resources have come under serious criticism. The critique has triggered endeavours to find alternatives without discarding knowledge itself.

For the common man, who suffers the adverse consequences of these developments, science and scientific language have become incomprehensible, making him totally alienated and dependent on the mercy of others. Further, the highly specialized language of science, the speed and complex nature of scientific and technological developments, and the lack of comprehension of the changes taking place have created apprehensions in the minds of people. The fear is further compounded by unpredictability of developments and their consequences and the lack of social control over them. As a result, a large number of single issue groups have come up who question the possible impact and consequences of technologies. At present, these voices and criticisms are raised by marginal groups, but they can gain momentum in course of time to marginalize science and all the gains which have accrued from its advancement .

It is, therefore, necessary to understand what has happened in the past and with what consequences. In the case of India during the medieval period, the general social unrest and the human effort to find self-satisfaction, achieve peace and tranquillity, and overcome ethical and religious disputes in a society beset with continuous warfare and uncertainty, found expression through the movements of Bhakti and Sufism.

A question arises as to why these movements and their possible relationship to the lack of scientific growth during the medieval period have not been studied in India. There could be three possible reasons for the neglect of the study of science in the cultural and social context of India.

Framework of History of Science in India

Firstly, Indian studies in the history of science have followed the European framework which is based on two factors: (a) chronological and compartmentalized arrangement of historical facts and events, divorced from social and political contexts—an approach that provides only a picture of linear development; and (b) a study of science as an apolitical, acultural and amoral subject.

Recent studies in history of science have not only negated this approach of tracking the linear development of science and technology, but have also brought out the importance of the social, economic, cultural and political framework of scientific and technological developments.

The European framework of history of science has also led to the marginalization of scientific and technological developments, prior to the industrial revolution, in the non-European culture areas, in particular those of China, India, central and west Asia. Further, it has projected science and technology as European phenomena.

Secondly, one tends to look at the past from within the contemporary framework, evolved over the years, as a result of the industrial revolution and the French revolution. The three components of this approach have been well defined by Professor Alan Mackay:[1]

1. The world can be changed by technology, which can be a motor for perpetual change or development. This ideology is an offshoot of the industrial revolution.
2. There is a science of society, an offshoot of the French Enlightenment, the seeds of which were sown by Diderot and Alembert's *Encyclopaedia.*
3. Science can be incorporated into a world view covering natural and social environment, beliefs on life and death, natural phenomena and cosmology. This has been made

possible by the accumulation and dissemination of knowledge during the present century, in particular.

The Concept of Culture Area

The nationalistic approach to history of science, as developed in Europe, when applied to India, as is being done today, misses a major folklore of science in India. This perhaps is the third reason for the neglect of the study of science in the social and cultural context of India.

The study of science in India, if confined to geographical and political boundaries of the country, will mean that the main features of scientific development, as well as of other intellectual endeavours in social and cultural spheres, indeed of an interacting civilization in Asia as a whole, are likely to be missed.

Asia has seen three major cultures—the Vedic, the Buddhist and the Islamic—each interacting with one another in successive periods of history. If a cultural map of Asia is drawn, one may notice that each of the three cultures overlap. In other words, the three culture areas in Asia have been in continuous dialogue—picking up ideas and technological developments from each other and incorporating and developing them in their own culture areas. Further one may also notice many common features in these culture areas. One of the most significant features is the emphasis on man—promoting self-discipline 'to look inwards in search of spirituality', developing a symbolic relation with nature, and evolving a defined culture in human relationship.

In the light of these remarks, it may be worthwhile to look into some of the philosophical and cultural features of India from the tenth to the eighteenth century.

II. THE FRAMEWORK OF CULTURE, PHILOSOPHY AND SCIENCE

A cursory glance at the period tenth-eighteenth century would reveal that man remained the primary motor for change. Consequently, all efforts were directed to provide a code of conduct for the individual, his dealings with others, and his use of materials. Social laws as codified in different religions were evolved over the years to this end.

Development was built around the improvement of man. This would be evident, for instance from Balban's advice to his son Muhammad: 'A king should, therefore, strive for the purification of his heart and his soul and should always be thankful to God for his blessings.'[2] Further, he said, 'if the king and his officers are honest and truthful, all the people in his dominion, young and old, women and children are drawn towards virtue, uprighteousness and justice.'[3]

The science of society was considered as the discipline of translating into practice what was ordained in sacred texts, like the varna ashrama dharma in Hindu society or the submission to the dictate of the king, considered to be the shadow of God on earth, amongst the Muslims. Both had, what could be termed as faith in divine action, which was sought to be interpreted through astronomy-astrology and natural phenomena or events of uncommon occurrence. Within this framework, people played politics to come to power and theories were developed to justify their actions.

Religion provided the universal language. Knowledge was divided into two compartments: first the interpretation of sacred texts, and second, what was obtained by observation and experimentation. But the latter's validity or credibility was subject to it being in harmony with what was said in the sacred texts, as was suggested and argued by the Shankaracharya in India, and Al-Ghazali in the Islamic culture area. In fact this reference to the sacred text became a major source of controversy and was used by religious scholars (Pundits and

Ulemas) and political powers to control the growth and spread of observational and experimental methods and the knowledge obtained through them.

It may therefore be desirable to look upon science as one of the elements of human intellectual activity, and to explore its relationship, if any, with the various social movements which emerged during this period.

In the context of the period under consideration, two features—one general and the other specific to the multi-cultural complex society of India are significant.

Firstly, as already mentioned, in every society science lost its momentum of development and social forces emerged which were either indifferent or antagonistic to science. The reasons for this phenomenon might be political, economic or cultural; they might also be due to lack of patronage by small states which then existed or due to continuous warfare.

Secondly, the philosophical and theoretical religion, like the philosophical and theoretical science, was limited to a very small number of people, who were patronized by the kings or nobles mostly in urban centres. As against this, the vast majority of people followed what could be called 'simple popular religion' and they developed their religious practices accordingly. The latter were often decried or denounced by religious scholars; and this was true for science as well. The scientific knowledge used in everyday life, though its source was theoretical knowledge, was used together with folklore, myths and superstitions, what Al-Beruni called the 'pearls mixed with cow-dung'.

Science in Everyday Life

In an agricultural society, science provided the calendar and the mathematics for working out revenues and taxes. It was also a part of many religious observances and various social and cultural activities. For instance, astronomical and astrological knowledge was extensively used for marriage ceremonies and casting of horoscopes, and dietary knowledge along with seasonal factors decided dietary habits. Yoga was developed for promoting health and strengthening the human system to meet the requirements of healthy living, dance and vocal music. Technological knowledge was used to meet everyday needs, in such areas as cloth making, printing and dyeing, food preservation and production of various drugs.

Since human society was predominantly an agricultural society, its needs and demands continued to remain at a level that could be easily met by the already developed science. The use of science in meeting these demands did not exclude further development of science to satisfy human curiosity and to develop cosmological and philosophical constructs. During the period under review, some of the most significant general statements were made regarding matter, life, and other aspects of knowledge.

This linkage of science with social, cultural and political activities of man has often been obscured by the widely held view that science is socially, politically and morally neutral. Boris Hessen was the first to make a dent in this view in his essay, 'Socio-economic Roots of Newton's *Principia*'.[4] This was later taken up by Benjamin Farrington in the 'Linkage of science with politics and cultural life of ancient Greece.'[5]

Efforts to control science and to limit the spread of scientific knowledge and outlook by making it the preserve of the elite was a major feature of society and culture in both Indian and Islamic culture areas. This might have been one of the factors responsible for throttling the growth of science in India and the Islamic culture area. There is a need to study such factors as the political, religious and social structures of society which thwarted the growth of science.[6]

The study of history of science in India got an impetus after Independence and a number of systematic, descriptive and some analytical studies were carried out. However, these were confined, by and large, to the ancient period; the medieval period did not get much attention. The few studies that were carried out did not provide any perspective, nor any clue to what really happened during this period, particularly with regard to the interaction of Arabic and Persian scholars had with Sanskrit scholars. A bibliography of source materials of books written in India in Arabic, Persian and Sanskrit, during the twelfth to the eighteenth century, lists about 10,000 manuscripts.[7] This vast literature still remains unexplored. It comprises annotated editions, commentaries, abridged editions of older manuscripts, translations, encyclopaedias, dictionaries and some books for teaching in schools.

The question which faces historians of science is: if this was the scale of scientific activity, and if India was ahead of Europe in this sphere till about the seventeenth century, why did this activity and interaction not result in a major scientific development?[8] It might be observed that whenever there was an interaction between the scientific activity of two culture areas, it provided a base for further development of science. In ancient Greece the interaction between ancient Egyptian, Babylonian, Persian and Indian science gave rise to a distinctly new scientific ethos. Similarly in west Asia, with the rise of Islam, it was the interaction between Indian and Greek science and the local knowledge base which gave a fillip to science in the Islamic culture area. If that was so, why did similar interaction not provide a take off for further development of science in medieval India? Why did the two interacting cultural traditions—the Turko-Persian and Indian—remain at the level of merely understanding the knowledge base and philosophical traditions and absorbing them in evolving their respective practices? Why did it not lead to the integration and synthesis of the two traditions to provide a base for this take off?

Possible Causes for Stagnation of Science

Various technological, social and economic reasons have been suggested for this stagnation. These have been indicated in the first chapter on 'Perspectives of Indian Science during the Medieval Period'.

Needham has suggested that the lack of scientific developments may have been due to the absence of the merchant class coming to State power. The same reason also applies to China and the Islamic culture area.[9]

Another explanation, often suggested for India, is the invasion of India by the Turks. In this context two points are worth considering. If this was the reason for India, then what were the reasons for China and the Islamic culture area not developing a theoretical science? Indian developments have to be seen in the context of Asia as a whole. Besides, if the Turkish invasion and its consequences were confined to the north, what was happening in the south? According to Dr Tara Chand, the centres of intellectual activity had shifted from north to south by the ninth century. Being the major centre for scientific and religious activity, during the early medieval period, south India was not disrupted by any invasion, and the southern empires might have attracted Sanskrit scholars from the north. Further, the south also had interaction with the Arabic tradition, but this was largely confined to religion, religious practices and cultural activities. This had a deep impact on many aspects of the social and cultural life of the south.[10] This interaction, however, is not evident in the field of scientific activity.

III. SOCIAL MOVEMENTS AND SCIENCE

A possible reason for the stagnation of science could be that human attention was directed more to the problems of social equality and harmony amongst different castes, ethnic groups and religious sects. In contrast to the contemporary period, the level of development of science in the medieval period was such that it could neither provide an understanding of the reasons that caused these problems nor could it offer any effective solutions. Consequently, effort was made to understand the problems at the human level, within the framework of religious philosophies, of both Hinduism and Islam. An effort was also made, as by Kabir and Guru Nanak, to discard the rigid and ossified religious framework, to find a way of bringing the people together to enable them to find solace and salvation individually, and to achieve social harmony through practice of a new value system. The development of Bhakti and Sufi movements has to be seen in this light.

The period tenth-eighteenth century was a period of growth of the Bhakti Marg, first in the south and later in the north. This was also the period of the introduction of the Sufi Marg and its spread throughout India. It would be worth enquiring if their growth had any impact on scientific development in the country.

Preoccupation With Mysticism

According to Abdus Salam, the growth of Sufi mysticism was the cause of decline of science.[11] A similar opinion was expressed by Nizami. According to him, *Tassawuf* along with other religious studies became a major preoccupation of scholars when 'Muslim society passed its meridian'. Further, the spirit of philosophical inquiry was discouraged and *preservation* rather than *investigation* became the *leitmotiv* of all scholarly endeavours.[12]

An interesting feature of introduction of Sufism in India, as Nizami pointed out, was that it was introduced at the very beginning of the establishment of Muslim rule and the latter's rise and spread all over India. In other words, it developed in a period when free thought and scientific research and development had been suppressed in west and central Asia in the early tenth century, as was pointed out by Professor Mohammad Habib in the introduction to Nizami's book.[13]

The question arises as to why the scholars, finding the rich reservoir of scientific knowledge in India, did not develop it further, particularly after Changez Khan's invasion of central and west Asia which was followed by mass migration of scholars to India in the thirteenth century.

In this context the late Professor Needham's remarks are worth considering. In 1946, in an essay he posed a major question: 'the deepest historical question that can be raised—why the body of systematized knowledge and theory about nature which we call science did not develop also in India or China.'[14]

This question continued to occupy his mind, and as he went deeper into this problem he discovered the development of different sciences in China, and only a few authentic efforts made in India. In 1971, writing a new foreword to his book first published in 1931, containing papers presented by the Russian delegation to the Second International Congress of History of Science, he said:

> With the appearance on the scene of intensive studies of Mathematics, Science, Technology and Medicine in the great non-European Civilizations, debate is likely to sharpen, for the failure of China and India to give rise to distinctively, modern science while being ahead of Europe for fourteen previous centuries is going to take some explaining.'[9]

Further, six years before his death in 1989, he organized a conference in Cambridge on the 'Dynamics of Oriental Societies', and he wrote to the Secretary, Commonwealth Science Council, on the purpose of the conference:

> The conference is meant to involve a multi-sided discussion aimed at bringing about greater and more realistic understanding of the specificity of the histories of societies such as China, India, Japan, and the Islamic world.[15]

The questions posed by Needham require a critical study of available literature, to seek the basic factors in all the three civilizations of Asia. In this context, some scholars had tended to isolate India and blame foreign invasion for the disruption of scientific activity. If this were so, then what were the factors operative in China, which had a well organized administration and a stable society? The question may be asked in regard to the disruption of scientific activity in the Islamic world.

Suppression of Free Enquiry

Three factors are often mentioned in the Islamic world: (i) The rise of Ashari school of thought (Al-Ashari, AD 930) which opposed and suppressed free enquiry. This might be so, but one of the great scientist of the period, Al-Beruni, was an Asharite. (ii) The large scale murder of scholars at the major centres of learning in central and west Asia by Changez Khan. But then, a large number of scholars did escape his wrath, and why did they not develop science further? (iii) The growth of Sufism, but here again, one of the early encyclopaedias of science—the *Epistles of Brethren of Purity*—was written by those who were, or could be taken as the founders of Sufism.

In order to look more deeply into the possible reasons and factors for the stagnation of science during the medieval period, there is a need to correlate economic, political, cultural and civilizational features of the time with the development of and containment of intellectual activities, on the one hand, and to study the change in direction of intellectual activities into channels other than science, on the other.

As has already been mentioned in the earlier chapter on the 'Perspectives of Science and Technology', the three civilizations of Asia had been in continuous dialogue in every field of human activity, till the time of their colonization or semi-colonization, followed by intellectual colonization. In this context, the period tenth-eighteenth century is critical for throwing light on the problem under study. In this period the knowledge—of philosophy, religion, science and technology—which went out from India was absorbed by other cultures—of China, central and west Asia; and after being absorbed, this knowledge again interacted with India, in different parts of the country, from different sources and at different levels. The rapidity and the degree of absorption was possible because of the many common features in the cultures of these civilizations.

IV. THE BHAKTI MARG

Bhakti Marg is defined in the *Encyclopaedia of Asian History* as a 'general name given to three sects of modern Hinduism which lay stress on the importance of *bhakti* or devotional faith, as a means of salvation', as opposed to the 'work path' (*karma-marga*) and the 'knowledge path' (*jnana-marg*). This definition of Bhakti does imply marginalization of science.

Little is known about the origin of the Bhakti movement. It first began in the south between the sixth and tenth centuries.[16] Dr Tara Chand felt that one of the possible influences might have been the advent of Islam. Muslims came to the western coast of south India in the eighth century and to the eastern coast by the tenth century; and by this time they had come to acquire considerable social and political influence. He further stated:

> It may therefore, be premised without overstraining facts that if, in the development of Hindu religion in the south, any foreign elements are found which make their appearance after the seventh century, which cannot be accounted for by the natural development of Hinduism itself, they may with much probability be ascribed to the influence of Islam.[17]

Further, Dr Tara Chand observed that in the south, philosophical and devotional schools of thought, though they had their source and inspiration from ancient systems, also revealed, 'the elements in their totality and in their peculiar emphasis a singular approximation to Muslim faith.'[18]

Commonality of Ideas

The probability of such influence increases, as we know, for those living in a port city, who may have come in contact with Arab traders and settlers. Trade, besides marketing of merchandise, was also a vehicle of exchange of information and ideas and diffusion of technology. The traders and those who came along with them—while they allowed others to observe their customs, practices, philosophies and cultural features—also imbibed these from the people of the host country. The dialogue was observational and oral. The possibility of diffusion became greater if there was some commonalty of ideas and practices. That some commonality was there between the two cultures was evident from the fact that one of the elements of Islamic knowledge revolution was Indian scientific and philosophical knowledge and its diffusion into the learned segments of the population of the Islamic world.

According to Dr Tara Chand ideas evolved in the Islamic culture area which were analogous to Hindu ideas and which could be presented to them without shocking them.[19] One of the objectives of Shankaracharya was to unite the Hindu society, and in particular to wean away the Jains and Buddhists and to bring them within the Hindu fold. The concepts of monism and Brahman were useful to bring together people belonging to different sects. The same role was played by the concept of monotheism in uniting different tribes who worshipped different gods in the growth of Islam.

The Character of Bhakti Marg

The Bhakti Marg, both in the south and in the north could not be considered as a single unified movement; it had many facets and its sources were diverse. Bhakti literature is an important part of Tamil literature. It is non-Vedic and its traces are found in Buddhist and Jain literature as well.[16] The Alvar literature reveals their antagonism to fasts and pilgrimages and inequality in worship. Alvars followed Vaishnavite tradition, while Nayanars were Saivite. The poems of Bhakti literature, 'elicit a sense of being in direct contact with the thoughts and emotions of the authors'.

One significant development in Bhakti was the effort by Ramanuja, who was credited with the integration of Vedic and Bhakti streams in Tamil Nadu through his doctrine of Dual Vedanta, to place the hymns of the Alvars on par with Upanishads. The literature of Bhakti Marg was in the language of the people, instead of Sanskrit. The Bhakti Marg was not a mass movement, though, nor was it a social reform movement, but its character was based on the reform of the individual. Every man or woman who became a Bhakt was for the salvation of the individual. It had streaks of egalitarianism, but it was not an anti-caste movement. However, those devotees who came from the lower castes did denounce caste.

According to Satish Chander,[20] the Bhakti Marg attracted the growing artisan class and merchants, on the one hand, and was also promoted with the emergence of new technologies, on the other. The latter covered such areas as architecture, making of horseshoes and iron stirrups, manufacture of high-quality glass, textiles, tailoring, etc. The practitioners of these sought egalitarian status since they were not content with their position in the Brahmanical social order.

The Bhakti Marg was also effective in weaning away Buddhists and Jains, and bringing them into the Hindu fold.

Most of the women saints, as also the male saints of north India, used the local language as against Sanskrit. The elitist character of Sanskrit, and the abstract philosophical thoughts it expressed distanced the ordinary people. Bhakti thus became a vehicle for the expression of emotions and feelings of people, and the assertion of the rights of the under-privileged.

The growth of Bhakti was indeed a part of the social turmoil and upheaval and the social ferment of the period due to two factors, internal and the other external. The internal factor covered the social impact of the rise and fall of dynasties, conflict with Buddhism and Jainism, internal religious debates and sectarian conflicts, and the reaction against a monistic, closed, ethno-centric environment, as a result of imposition of a pristine model from above which did not allow for variety, individuality and emotional satisfaction.[10]

The external factor included the activities of Sufis, due to the Arab traders and others settling first in the south and later in the north. The latter may also account for the late rise of Bhakti Marg in north India.

The reason for the emphasis on the salvation of the individual might have been due to the focus of religions on individuals, through the various practices of ascetic-seclusion, meditation, fasting, etc. This ethos was in common with the Sufis. The lack of development of social consciousness, which was the basis of social reform or change, might also have been the result of this emphasis on the individual.

Scientific knowledge, as it existed in that period was the preserve of discrete groups, mostly the Brahmins. It was too theoretical with its philosophy and logic to be of any use in everyday life. Further, the framework of that knowledge did not provide an alternative view of life, other than what was sanctioned by religion.

Revolt of the Individual

Knowledge, as in religion, in its pure form, with its philosophy, logic, practices and rituals, was also confined to the learned and the elite. The popular religion, though its source lay in theoretical religion, was a mixture of popular beliefs and practices. Bhakti represented a revolt against the rituals and austerities of the theoretical religion. It both appealed to feelings and emotions of the people and provided them with an opportunity to express themselves and search out their own way of salvation. It was, indeed, the revolt of the individual.

By and large, it were the people who were marginalized by the hierarchical society who found in Bhakti an opportunity to assert themselves. Their language was the language of the people, as against Sanskrit, and their message was simple. They spoke in a language which reflected both their social background and their profession. For instance, said Ravidas:

> I've never known how to tan or sew,
> Though people came to me for shoes.
> I haven't the needle to make the holes
> or even tools to cut the thread.
> Others stitch and knot, and tie themselves in knots
> While I, who do not knot, break free.
> I keep saying Ram and Ram, says Ravidas
> and death keeps his business to himself.[21]

Or take, for instance, the following couplet of Kabir:

> The master weaver, whose skills are beyond our knowing,
> has stretched his warp through world.
> He has fastened his loom between earth and sky,
> where the shuttle cocks are the sun and the moon.
> He fills the shuttle and weaves an endless pattern.
> But, now says Kabir, the weaver! He breaks apart his loom
> and tangle's the thread in thread.[21]

The impact of Bhakti on women requires a detailed study. Dr Vijaya Ramaswamy in her chapter[22] in this volume on 'Women Saints of Medieval India' has described and analysed the lives of 75 women saints of south India. What came out of this study was that Bhakti represented a medium of expression of the self in the case of women. Those who came from the high castes served as role models, while those who came from lower castes became also an instrument of revolt against the caste system. The language they used reflected the productive processes in which they were engaged. The revolt against the caste system was beautifully expressed by Auvaiyer (twelfth century):

There are no castes but two if you want me to tell
The good men who help the poor in distress
The other, that will not so help
These are the low born.

In the north we had Mirabai and Lal Ded. Mirabai exhibited fearless defiance of the confines of customs and status in a feudal household, on the one hand, total submission, humility and self-sacrificing nature as a devotee of Krishna, on the other. The former role was aptly described by Hawley and Juergensmeyer:[23] 'She is celebrated as the kind of person who shattered, wherever she went, particularly by making it clear that the worlds conception of women's place is not always a place one wants to be.'

Lal Ded in Kashmir revolted against the caste system as also the male dominance. She differs from other women saints in that in her poetry she speaks of equality of Hindus and Muslims. She also accepted the concept of Pir (Guru) as a medium to reach God:

Siva, abides in all that is, every where
Then don't discriminate between a Hindu and Musalman
In thou art wise, know thyself
That is true knowledge of the Lord.

The Guru gave me only one word;
Enter into thyself from the outer world;
That is why I started dancing nude.

She had inspired Nuruddin Rishi, who acknowledged his debt to her with the following verse:

The Lalla of Padampore
Who had drunk to the fill the nectar
She was an avatar of ours
O God, grant me the same spiritual power.[24]

Lal Ded explicitly recognised the impact of Islam, and her association with Nuruddin Rishi indicated a bridge between Bhakti and Sufism.

Revolt against Particularism

Bhakti can also be taken as a revolt against Brahmanical particularism, an assertion of the rights of the under-privileged, promoting equality, variety and individuality as against the monopolistic Brahman-centric environment. Its expression and the language of expression differed from person to person from Alvars to Ramanuja, from women saints Mirabai to Lal Ded, from Ravidas to Kabir, and from Tulsidas to Guru Nanak. As one could infer from the writings of the Bhakts, religion was presented as a matter of experience rather than the following of rituals.

Bhakti was practiced within the framework of religion, for salvation of the individual. Different sects found their own way to achieve their salvation. Different groups who practiced

Bhakti could be ranged from orthodox to those who adopted radical and heterodox attitudes, like the Vaishnavites in the south and Kabir in the north.

Different social, cultural and political factors seem to have played a role in the origin and promotion of Bhakti in different parts of India. The power of Brahmin and Kshatriya castes in different regions and the emergence of new technologies and professions seem to have also played some role. In addition, a major factor could have been the emergence of Islam and Sufism in India, with their concept of equality and absence of castes. The interval of about 500 years between the beginnings of Bhakti in the south and the north might have been due to different political and social conditions, but this might also have been due to early arrival and impact of Islam in the south as compared to the north.

The religious nature of its upsurge and its nature, as also the social and cultural dimensions of Bhakti have been explored to some extent. But some of its linkages with intellectual activities and cultural movements remain to be investigated. Did the Bhakts, through their practices, apart from getting individual solace, hope to give a meaning to their lives or prolonging their lives? What was their contact with any Rasayana practices, particularly of those who came from the artisan class? Was there any link between Bhakti and Tantric practices, which were quite common in those days?

Further, we do not know how many of the Bhakts had an education or proper understanding of scientific knowledge of the period. Ramanuja and others, who came from upper castes, had this knowledge, but did it apply to all? Or did many of them, particularly those who rejected caste, also reject natural knowledge? Or did they limit themselves to folklore and popular knowledge?

Despite the prevalence of Bhakti, and the presence of a number of Bhakts in different parts of India, Bhakti could not become a movement. Groups formed around different Bhakts to propagate their messages. Only Guru Nanak laid the foundation of a religion and Sikhism became a movement of social and religious reform.

These and other dimensions and the questions mentioned above require further study.

V. THE SUFI MOVEMENT

The knowledge in the Islamic framework was divided in *Ilmal-Adyan* and *Ilmal-Dunya*—that is, knowledge of the religion and knowledge of the world (including the natural sciences). The corresponding Sufi nomenclature was *Ilme-Batin* (knowledge of the self) and *Ilme-Zahir* (knowledge outside the self).

The people were put into four different categories according to the manner in which they sought knowledge:

1. *mutakallimins* who indulged in dialogue and debates:
2. philosophers and rationalists, who used logical analysis aimed to arrive at truths;
3. those who were guided by an established guide, *Pir* or guru; and
4. Sufis, who concentrated on inner-self, lead an ascetic life and concentrated on *Ilme-Batin*.

Predestination Versus Free Will

Sufism in fact was not one single system. It was as complex as the various trends in medieval life, society and culture woven together. The medieval time was dominated by the mysteries of life, which the human mind was unable to fathom: the decay of beauty, of natural things and their impermanence, on the one hand, and the birth and.purpose of life, the life-after-death, and the mysteries of soul, on the other. Moreover, the elite and the highly educated did not find any logic or rationality in the running of human and social affairs. And lastly, there was the utter helplessness of humans, who despite their knowledge and reasoning power, could not fight their destiny; in other words, the were caught in the trap between predestined action and free will.

To fully appreciate the social and cultural ethos, the uncertainty of life, the purpose of life and the problems of human destiny, it may be worthwhile to quote Omar Khayyam, the mathematician, astronomer and philosopher, with his mind roving over these problems. What happens to men? They turn into dust! Let us have a look at some of his verses:[25]

On the impermanence of life:

In that palace, where Jamshed held his bowl, the gazelle gave birth to the Young and the fox rested. Did you see how Bahram, who caught wild asses all his life, was caught himself by the tomb? (7).

The dust which is under feet of every ignorant one is the palm of a fair and the face of a sweet heart. Every brick that is on the battlement of a palace is the finger of a Vizier or the head a Sultan (30).

In every plain where there has been a bed of tulips it has grown from the rosiness of monarch's blood. Every thing of violet that springs from the dust has been a beauty spot on sweet hearts cheek (49).

O, Wheel of Heaven, destruction is out of your spite, tyranny is your ancient habit. O earth, should they open your bosom, many previous gems (will they find in it) (12).

On the nature of knowledge and life itself:

This sea of existence has come out of the unknown, there is no one who can pierce this pearl of knowledge. Every one has said something based on (vain) imagination. No one can tell as it is (14).

From the globe of black clay to the height of Saturn, I have solved all the major problems. I have opened difficult knots with cunning. Every knot has been opened except the knot of death (119).

In the cycle of coming and going neither a beginning nor an end is visible No one can utter a single word on this subject—whence it is coming and whither it is going (34).

The cycle of coming and going is also a reference to natural phenomena and in the case of human life perhaps to the transmigration of the soul.

On human life and its tribulations:

The good and the bad which are in man's nature, the joy and the sorrow which are in one's fate—leave not your affairs to the care of the wheel, for in the way of wisdom this wheel is a thousand times more helpless than you are (48).

The reference to the wheel is to indicate astronomical phenomena. Here the poet seems to suggest that neither natural phenomena nor human life have any control over themselves. Throughout his poetry the wheel and its movement are prominently depicted.

On religion:

I saw a knave sitting on the gray horse of the earth who knew neither heresy, nor Islam, nor the world, nor religion, nor God, nor truth, nor law, nor Certitude. In both worlds who has the courage for this (14).

On the division between those who strive for spirituality and those who try to gain natural knowledge:

O, thou who has come from the spiritual world with zeal and haste, and is bewildered by five and four and six and seven. Drink wine, for thou knowest not whence thou has come. Be merry for thou knowest not whither thou wilt go (11).

In this couplet, four refers to the four-element theory of matter, five to the five senses, six to the six directions, i.e. geography, and seven refers to the seven planets, i.e. astronomy. He thus emphasizes the division of the two modes to knowledge.

While the last couplet brings to the fore the schism between the natural sciences and those who sought a spiritual life, in an earlier couplet (5) he stresses the nature of knowledge as a construct of imagination. His major theme remains the lack of purpose of life—that is, one does not know where one comes from and where one goes—and the unfathomable nature of death.

While Khayyam suggested that one should enjoy life, others sought different avenues to give a purpose to their lives. Some tried to gather groups around themselves, others wielded the sword and found for themselves small territories or kingdoms and still others endeavoured to gain patronage of kings or noblemen to have security. Noblemen and those holding high offices, uncertain of their future, never knowing when palace intrigues would put them in disfavour, when their positions and their very lives would end, tried to make the best of it, by having festivities. Many other, who wanted to escape this turmoil and uncertainties of life, sought solace in spiritual life, by becoming recluses. Many amongst them, having gathered a large number of devotees, tried to influence the kings, while remaining, outside the circle of intrigues and turmoils.

In this ethos, scientists, such as they were, had very little role to play, except as functionaries of the kings to advise them on revenues, taxes or establishment of laws. More so, their role was important as court astronomers-astrologers, to interpret heavenly signs, to foretell the future and to warn the kings of possible dangers. Outside this circle were artisans and craftsmen, both in villages and in urban centres, and the peasantry in villages, who continued with their work. The peasantry provided the basic necessity of food and the artisans and craftsmen met other needs as well as the demand for luxurious goods by the rich and the powerful. Their implements were most rudimentary and simple, but they were able to produce fine products through their acquired skills, living a simple life, often of bare existence. Their piety and satisfaction and the purpose of life was reflected in the pride they had in their skills and products.

Origins of Sufism

Under these conditions of uncertainty and shortness of life , destruction and decay, people yearned for a peaceful and long life, with some degree of certainty. They desired their name and fame to continue after their deaths. For this purpose, the rich and the powerful tried to construct magnificent buildings, places of worship, palaces and tombs. Literateurs and poets achieved this through their works, artisans and craftsmen through their products.

There were, however, other streams for prolongation of life and for attaining immortality. For example, through alchemy, men endeavoured to produce the elixir of life for prolonging life or even achieving immortality. Another was Sufism. Sufis, through various practices like fasting, meditation and other means (common with Hinduism or adopted from it) they strived to purify the soul, to attain the status of *Insane Kamil* (i.e. the perfect man) so that, finally, at their passing away, the soul would meet its ultimate goal. It is interesting to note that an early book of the tenth century AD *Kashful Mahjub* by Ali Hujwari (known as Data Ganj, and buried in Lahore), advocated *Hallul* (i.e. transmigration of soul). The inclusion of this concept from Hindu philosophy, of transmigration of soul in an early text, is quite significant.

Among the major beliefs of the period were the concepts of Macrocosm and Microcosm—the universal and the human systems, respectively. The Macrocosm was reflected in the Microcosm and the release of soul from humans and its unity with the universal soul, came to be the ultimate in Sufi philosophy and the main objective of their practices.

It is most interesting to find commonality of approach between Hindu and Muslim practices. In India the alchemical route was through Rasayana and Tantric practices, to which yogic exercises could be added. The Sufi tradition had its similarity in practices with the

Bhakti and the ascetic practices of the Brahman. This commonality of approach represented similar goals towards which humans aspired, although the similarity of practices was the result of interaction over centuries. This is also brought out by Al-Beruni's observations.

Dr. Mahdi Hasan[26] in a perspective paper suggested a link between alchemy and Sufism:

> Sufism began as an offshoot of alchemy, a cult of immortality. It was obvious that once man was assumed to be immortal, it was the end to which the man could aspire.

This was also the aim of.their systems like yoga and Sufism. Here, Al-Beruni[27] informs us: 'Rasayana (or Indian alchemy) according to Patanjali is also a method of liberation from cycles of reincarnation according to Hindu philosophy which finally ends with immortality of man. Patanjali was the master of yoga system so that his approval of Rasayana is the best indication that yoga and Rasayana share a common aim.'[28]

Further, even Ibn-Arabi tried alchemy but found Sufism a better and sure system. Jabir Ibn Hayyan called himself a Sufi, and not an alchemist. According to Max Mueller:

> We must not lose sight of the antecedent in that we may see how physical religion leads to moral religion.[29] In our case we have to see how drugs coming from outside, in nature, give in to powers found inside the human system, and these being developed proved even superior. The former method by its nature could be called expensive, the latter intensive.[30]

As one looks back at both alchemical practices and Sufi endeavours one feels that, in the absence of biological knowledge, such as we have now, and the functioning of the human system, the concept of soul was developed, since physical body could not survive the knot of death, as Khayyam said, to attain immortality . In contemporary society, the alchemical route is being developed, by marginalizing the Sufi route through the development of bio-medical science. The possible reason for discarding the Sufi route is the rejection of the concept of soul by the contemporary studies in biology and the human system. The endeavour to prolong life is being affected through artificial organs and organ transplants. The more intensive effort is being undertaken through modifying genetic code to control degenerative diseases, the process of ageing and to prolong life. Will these help to achieve the goal of immortality? Only the future can tell. Perhaps, if further development of biological knowledge brings in the concept of soul, in one form or the other, then the Sufi route in a modified form could be taken up again.

This is only one of the many dimensions of Sufism. It may be worthwhile to touch upon other features, connected with its development in different periods.

Attitude to Knowledge

As regards their attitude to knowledge, most of the Sufis had traditional education and were well versed in logic, philosophy, mathematics, perhaps even medicine, astronomy and astrology, apart from theology. Their search for reality, according to Ibn Bishrun, was aimed at knowing 'what exists, what brings into being and how it came into being',[31] which according to Mahdi Hassan represented three phases of 'Reality': form, function and origin. The method of teaching involved debates, seminars and commentaries on older texts, and the students moved from one lecturer to another based on their specialization and what they were seeking.

Sufis believed that their main aim was to know the attributes of God, to investigate freedom of will and predestination. For them faith was the central feature of their endeavour and it alone helped one to arrive at proper conclusions. Besides, they believed that meditation helped one to have revelations as to the attributes of God and mysteries of life and nature; it also helped one to see the reflection of God in every creation and the latter's functioning.[32]

Knowledge of nature, and how it works through observation, experimentation, and logical analysis, was of not much use to Sufis, because they saw in natural phenomena the attributes of God, a reflection of his power, omnipotence and his omnipresence. This according to them could be arrived at by meditation, and development of spiritual powers, which when fully developed could enlighten the seeker through revelations. Thus, they felt that true knowledge, or knowing the reality, could not be obtained through observation and experimentation but through revelation.

Further knowledge could be attained by only those who by nature and experience (i.e. spiritual experience) were qualified to receive it. They felt that the knowledge of divine attributes covered all other sciences. For instance, Karl N. Ernst[33] quotes Ibn Arabi (d. 1240) as saying that the universal theophany of divine attributes through creation made the knowledge of Sufis all inclusive. He also quoted Wasti (d.932): 'I sought God in clarity but found him in obscurity'; Hallaj (d.922): 'Knowledge is concealed in unknowing and unknowing is concealed in knowledge'; and Abu Yahya Al-Shirazi: 'Wonderment has a beginning and an end. Between the two wonderment knowledge appears when men attain learning and tradition and authority: however, they do not enter reality, because of the limitations of their understanding and the proofs of their sciences. Beyond that knowledge, wonderment within wonderment becomes manifest and one never comes out of that wonderment.'

The division between the endeavours of Sufis and those seeking knowledge through observation and rational analysis, which was indicated by Khayyam in his couplet (10) quoted earlier, was also indicated by Ibn Rushd in a different context, in the interpretation of Sura 3:7. If in this Sura a period was introduced in the middle then, according to Rushd, it was meant for those for whom religious knowledge was essentially a matter of faith; but if the period was omitted than it was meant for those who could interpret the scripture in accordance with their knowledge of truth—that is, in accordance with available knowledge obtained through observation, demonstration and rational analysis.[33]

There appears to be during this period in the Islamic culture area, as in other cultures, a containment of knowledge within the elite group, while the ordinary people had to be content with some cut and dried knowledge to be accepted as basic truths and as matters of faith. This attitude was rather surprising amongst the Sufis, despite their revolt, if one could call it that, or despite the departure from the cut and dried, ossified Islam of the Ulemas. Their differences with the Ulemas were at both social and spiritual levels. They emphasized personal experience and fulfilment of religious spiritual strivings and promotion of mystical and moral sensibilities and, consequently, one expected them to allow every individual to seek knowledge in his own way.

The Sufis, as mentioned earlier, adopted most of the practices of Hindu ascetics—seclusion, ascetic life, rejection of worldly goods, fasting, meditation and contemplation. In the observance of their practices they endeavoured to reconcile exoteric (*zahir*) and esoteric (*batin*) into a harmonious relationship. Their major difference with the Hindu ascetics was in the observance of Islamic Shariah, as interpreted by them. Further, even though they remained outside the turmoil of social life they endeavoured through selflessness and dedication to serve fellow human beings. While remaining outside the social life of feudal society, as a recluse, they aimed at providing succour to the people, to communicate their message effectively, and in that they thought to save society.

Mysticism and Science

The origin of Sufism lay in mysticism (*Tassawuf*), and one could discern from the very beginning two trends—natural mysticism and the esoteric. Before the two trends are discussed it may be worthwhile to briefly discuss the linkage of mysticism with science.

According to Joseph Needham the development of science owes much to mysticism. For instance, the scientific reforms initiated by Francis Bacon, were 'put forward as part of a mystical interpretation of the Christian religion' against medieval rationalization and with an emphasis on observing nature.[34] He further stated that the 'association between nature-mysticism and science' was embedded in post-renaissance scientific thought.[35]

Newton, who is considered to be modern scientist in most studies, was in a sense a mystic and was also an alchemist. His involvement in chemistry was perhaps as a part of his mystic belief. How far his theory was part of his mystical beliefs requires to be understood.

The major link in Islam between *Tassawuf* and scientific knowledge is found in the works of the *Brethren of Purity* (tenth century AD.) According to them man could free himself through knowledge to attain spiritual freedom and salvation. They accepted the existence of mysteries which could not be comprehended through reason. The Brethren in their *Rasail* quoted the sources of knowledge they put together:

> It is true, we obtained most of the sciences from the preceding philosophy as others now receive them from us. Such is the way of this world—for one people to derive benefit from another. Thus it is the Persian sages obtained their astrology, and the sciences of observation (of the heavenly bodies) from the sages of India. Similarly, the Israelites got their knowledge of magic and talisman from Solomon, the son of David.[36]

Nasr has summarized the contents of the *Rasail* according to various sections covering different sciences. It may be worthwhile to point out here that they were not isolated but part of the Arab Renaissance, which could be considered as the scientific revolution of the tenth century AD. The language of this revolution was Arabic in which people of different ethnic groups participated, and which absorbed the knowledge previously developed by different culture areas. The second important feature, as indicated in the *Rasail*, was that the diverse sources from different culture areas became part of the knowledge system. All those who participated in this knowledge revolution drew from different sources—Greek, Hebrew, Syriac, Iranian and Indian. And as Needham has pointed out, their general philosophy could be called 'eclectic gnosticism'.

It may be worthwhile to indicate the contents of the *Rasail* based on their categorization:

I. *Primary Science*: reading, writing, business transactions, magic, alchemy, handicrafts, biographies and other similar areas;
II. *Religious Science*: revelation, exegesis, hadith, jurisprudence, law, asceticism, *Tassawuf*, interpretation of dreams;
III. *Philosophical Science*: (a) mathematics, geography, music, educational science, various scientific disciplines, logic, actions and sayings of the Prophet; (b) natural sciences—covering nature of matter, movement, time and space, meteorology, formation of minerals, knowledge of plants and animals, study of human system, philosophy, embryology, sense perception, limits of human knowledge, life and death, soul, languages and calligraphy; (c) psychological and rational sciences—covering intellectual principles, microcosm and macrocosm, cause and effect, essence of passion, resurrection, periods and epochs; (d) theological sciences.

The contents as indicated here in an abridged form bring out clearly the wide coverage of practically every aspect of nature and life, without any division between what we call natural sciences, religions, religious philosophies, psychology, history, social and cultural phenomena, literature and mysticism. Though the *Rasail* were, and could be considered as, an encyclopaedia, if one were to look at the works of the scholars of the period, their scholarship would reflect a similar totality, although historians of science have categorized them as mathematicians, geographers, physicians, etc. They had views on all these topics, wrote on them and even got into controversies raging during their time.

The link of natural sciences and *Tassawuf* continued in the works of Ibn Sina and other contemporary philosophers who visited Sufi sages. They interpreted the religious philosophy (not that of Ulemas) with natural philosophy, as they thought that there could not be two orders of reality and they believed in the unity of existence. Hussein Nasr stated that the philosophy in the Islamic world differed from the rationalistic philosophy of the western world. In the Islamic world it acted as a guide which led the human soul from the debates of logic to gnosis.[37] Thus, emphasis on philosophy as a guide to soul was part of the system of thought in which man was the motor of change in social development.

Ibn Sina played a major role in the development of Sufi thought and practices. According to Dr Tara Chand,[38] 'he conceived of the ultimate reality as eternal beauty, whose nature being self expression, it saw itself reflected in the universal mirror. This self expression is love, for love is appreciation of the beauty, which is perfection. Love is thus the moving energy of the world, it makes beings strive after their original perfection from which in creation they've travelled away, and it is by love that the human soul realizes its unity with the ultimate reality.'

This strain of thought is found in Al-Beruni as well, who visited India. He stressed the study of natural sciences for developing religious life, because creation, astronomical phenomena, plant and animal life and other features of this world were a reflection as well as the attributes of the Creator. And all living beings, including man, lived and moved, grew up and died according to the plan of their Creator. An underlying feature of Al-Beruni's works and philosophy was that he drew in from divergent sources—Greek, Indian, Egyptian and other earlier civilizations—and the knowledge was integrated within the framework of Muslim attitude to nature.[39] When the links between the natural sciences and Sufi philosophy snap could not be pointed out, but the dominance of Ibn Arabi's philosophy during the twelfth and thirteenth centuries appeared to mark the beginning. This was despite the fact that study of natural sciences continued to be part of the education of Sufis.[40]

Political and Social Action

Sufis were not involved directly in political activity, though some of them might have had linkages with the kings and nobility and enjoyed their patronage. Since they believed in social service (*khidmat-e-khalq* or service to the people), there appeared to have been groups of Sufis and individual Sufis who did interact with artisans, craftsmen and peasantry to uplift their condition. One such group was the Qarmatians. According to Needham, they were what we now call socialist in character. They stressed tolerance and fraternity, and organized workers and artisans in guilds. He further stated, 'That an alliance of this kind should have existed between mystical scientists and the organized workers is not in the least surprising, since... the great cleavage lay between those who were prepared to engage in natural operations, and those who considered them unworthy of a gentlemen. Between techniques and magical recipe there was no wide gap.'[41]

In India Qarmatians and Ismailis were instrumental in winning over peasants and tillers, labouring and artisan classes, many of them Buddhists. Those belonging to Mahayana system of Buddhism found common points with their philosophy and then accepted it.[42]

Near Jhatta in Sindh, now in Pakistan, Sufi Shah Inayat, during the reign of Aurangzeb, was greatly moved by the poverty and poor conditions of the peasantry, which was oppressed by landlords and other functionaries. Therefore, apart from preaching Sufi doctrine of equality and fraternity, he also preached and promoted the concept of cooperative farming. Of course, for doing this the Sufi was arrested and killed. As he was being killed he recited a couplet, reflecting Sufi philosophy:

> (You) are releasing me from the imprisonment of life, May God give your reward in both the worlds.[43]

His major complaint was that most of the Sufis and scholars had become covetous and aspired to gain worldly goods, forsaking the tradition of Sufis and scholars.

There is another example from Aurangabad—of Mahmud Shah Musafir. Musafir means traveller, and every Sufi thought that he was a traveller in this world, and he had to prepare for his journey to next world. Mahmud Shah must have been an engineer, for along with the madrasa he established he constructed a water-mill, for grinding the grain for the students. For running the mill he created a waterfall of sufficient velocity to turn the blades of the mill. The waterfall was created through a diversion of the water system he developed for the city of Aurangabad. The water was brought from a spring in the mountains through a covered channel of sufficient width to provide for the people of the city. This was a very ingenious and effective system. Some years ago, when there was an acute shortage of water in the city, due to drought, the system was revived by the city administration and it turned out to be quite useful.[44]

There are no other examples in India of such a role of Sufis, or perhaps this dimension has not been studied. The studies which have been carried have only emphasized the esoteric dimension of Sufism.

The transformation of natural mysticism, and mysticism which is associated with social action, to change the condition of the people, takes place when the possibility of social change is not there, due to suppression by powers that be, as it poses a danger to them. Then the mystical system acquires a purely religious and unworldly form. This was not peculiar to India, as we can see in the nature of the Bhakti and Sufi movements, but also happened in China and Europe, as pointed out by Needham.[45]

The Sufi stream came to India when Sufi thought was delinked from natural mysticism or was not playing an active role in bringing about any social transformation, as the Qarmatians or Shah Inayat had tried to do. It was institutionalized into different *silsilahs* and each confined itself to a *vilayat* (i.e. domain). The major *silsilahs* in India were the Chisti, Qadri, Naqshbandi, Suhrawardy. Abul Fazl in *Aine-Akbari* gave a list of all that existed during his time, with some details of leading Sufis.[46]

The Sufi way of Living and Thinking

In India the Sufis concentrated in developing practices of intense devotion and lived ascetic lives. Hamiduddin Nagauri produced his own food and kept a cow. They kept fasts and ate little and that too simple food. They preached love and amity amongst people and did not differentiate between people of different castes or religions. They preached what they practised themselves. They preached against arrogance, hypocrisy, covetousness and pursuit of material gains, and emphasized kindness, tolerance, generosity, compassion and honest living. Their major role was to bring harmony amongst the people, by rejecting over-intellectualization of religions and theological disputes. They practised a simple form of worship and suggested to the people that the highest form of worship was to help the needy and to serve the people.

The Sufis in thought and practices attempted to reconcile the thoughts and practices of different religions. They preached unity of God and brotherhood of man. Sheikh Abdul Quddus of Gangoh, for instance, said, 'What is all this noise and controversy as to who is a pious Muslim and who is a *kafir*, who has submitted to God and who is the sinner; who is following the correct path and who is not; who is Muslim and saintly, who is the atheist: they all belong to the same tradition.'

Mirza Mazhar Jane Janan, talking about Hinduism, said that it is not easy to call anyone *kafir.* He considered the Vedas as sacred, revealed books and called the Hindus *Ahle Kitab* (i.e. People of the Sacred Book).

Sufi language was the language of the people and they provided consolation and solace to the people in times of distress and difficulty. They accepted the social order as it existed with all its limitations and defects and concentrated on reforming the individual by developing positive virtues. Their view was that knowledge of philosophy or science as it existed at that time, through its application, could not reform society, nor bring about social changes nor bring the people together. Apparently, having convinced themselves of this they operated in a limited manner in concentrating on man. However, in doing so they brought about social transformation by promoting equality, helping the underprivileged, and developing a harmonious cultural ethos through mutual understanding of different forms of worship.

The growth of Sufis, apart from their practices and institutionalization into *silsilahs,* has to be seen in the context of a multi-cultural and multi-religious society striving to maintain its multi-facetedness and yet provide harmony in the manner of beads put together to make a necklace. This was evident at different levels. At the level of the administration and the state one could notice Akbar's efforts, which were fully reflected in *Aine-Akbari:* it was both a political statement an account of the cultural ethos, not circumscribed by religious prejudices—a secular statement with an Indian meaning. When linked with Al-Beruni's book on India, one got the feeling that it was the flow of the same stream—except that it represented a greater degree of understanding and imbibing of the Indian tradition. The other effort of Akbar at the religious level, the establishment of *Din-e-Ilahi,* was not successful.

At the cultural level, the intensification of interaction and the emergence of creative activity could be seen in architecture, literature of Rahiman and others in the north, and the endeavours of those in the east and the south. This was reflected in the development and promotion of different languages as a medium of communication between the people. In the field of science, the process started with the translation activity. With the passage of time the transfer of knowledge from one tradition became evident and was reflected in the literature of the two classical languages. It was only in the work of artisans and craftsmen that a single tradition was evolved, as they professed different religions and came from various regions of India and yet worked together.

Contribution of Dara Shikoh

The Sufi line of thought found its highest expression in the works of Dara Shikoh. His translation of the Upanishads entitled *Sirr-i-Akbar* (The Great Secret) into lucid Persian, according to Tara Chand, was responsible for the introduction of Upanishads to Europe.[47]

In his book *Majmual-Bahrain* (Confluence of Oceans), which actually was a reference to the coming together of Hindu and Islamic philosophies, thoughts and religions, Dara Shikoh endeavoured to point out their common features, the way they adopted the basic thoughts of each other, and their future development in each tradition.

In writing these books, it appears that Dara Shikoh's aim was not to unify all the religions into one, but by bringing out the basic principles he wanted to show the similarities to remove the antagonisms between followers of different religions, to enable people to develop a harmonious society. He tried to keep the multiple dimensions of a multi-cultural and multi-religions society, instead of promoting a unified tradition, and straight-jacketing the multi-faceted culture into one, which was bound to fail. The latter approach was evident from the efforts of orthodox religions, which represented cut and dried patterns for every one to follow, instead of finding their own path based on their own experience. This dimension of Sufi thought and practice was beautifully expressed by Shah Khamosh of Hyderabad:

> Kufr Kafir to Bhla, Sheikh to Islam Bhla
> Ishq Aashiq to Bhla, Apna Dil Aram Bhla
> (Let everyone find peace in following his own path—of Kafir in his practice or Muslim in Islam or lover in his love).

Dr Tara Chand in his introduction to *Sirr-r-Akbar,* referred to the significance of the efforts of Dara Shikoh in the following words:

> Three hundred years ago Dara Shikoh launched his Persian translation of the Upanishads in the faith that by making these books which enshrined in them the best and the highest thoughts of the Hindus available to the non-Hindus, he was paving the way for a unity of minds among the great communities of India. Today a world driven by differences is poised on the brink of disaster. Its future depends upon the removal of the fierce antagonism which afflicts vast human groups. To promote the process of healing and conciliation no more potent instrument exists than the propagation of the great books which embody man's deepest thinking on a subject most vital to human welfare.[48]

Unfortunately, these texts are not available, at least not easily accessible. Dr Tara Chand wrote the introduction to *Sirr-i-Akbar,* but the full text is not available in English. There is a need to study these texts critically particularly in the context of the contemporary situation.

VI. SUMMING UP

Every society has to blend into a harmonious whole four dimensions of human activity. These are not isolated but are interacting all through:

1. *Intellectual activity* covering knowledge of the environment and Nature, to find underlying principles and processes at work.
2. *Productive activity* covering material goods to meet the daily and basic needs of the people and to make artifacts to produce them.
3. *Social organization and political system* to bring people together, in the act of living, and to organize different types of activities.
4. *The emotion and feelings* of individuals within the framework of the society—their aspirations, hopes and fears and their desire to have a peaceful life with a certain degree of certainty and creativity.

The harmonious development and proper balancing of these four dimensions has not been possible in any society. In the medieval period, religion provided the framework of society at the community and state levels. The state allowed intellectual activity to grow, to begin with, but later curtailed it for reasons of sate policy, even though confined to discrete groups and made subject to the framework of dogma. The religious experience, instead of developing into spiritualism, was put in a straight-jacket of laws and rituals. It was also made a subject of philosophical reasoning and logical disputation. As a result, religions failed to play the role of bringing about a harmonous process of living. People, therefore, had to develop their own beliefs and practices. *Bhakti* and *Tassawuf* represented people's revolt against the ossified practices, in search of, and as an endeavour to bring harmony in life.

In contemporary society, the knowledge and technology complex have come to dominate social, political and economic institutions, which have been so organized as to meet the needs of the science-technology complex. The invasion of technology in the human lives has increasingly reduced human contact; the use of computer and e'mail communication are further renewing the necessity of human contact. Handling of computer and its operation have a tremendous effect on literacy and the understanding of the principles on which it works. The television and the video are replacing in-depth quality of understanding and reflection on all kind of issues and problems with quick images.

The impact of scientific and technological developments has brought to the fore the problems of environmental degradation, pollution, etc.—that is, practical consequences of knowledge. In addition, those who generate, develop and control technology today have only profit as their major consideration, the questions of morality and other human considerations have no role to play. The incomprehensibility of the technological process and its consequences, in particular the abundance of destructive weapons, is a case in point. Every invention brings in both advantages and disadvantages, and hence people have suspicion and fear of its adverse effects. This also brings in uncertainty and the fear of the future. The alienation the people experience leads them to reject the scientific method, principles and philosophy. This is being voiced now by a section of the people, while some others are critically examining the efficacy of the scientific method for acquiring knowledge, its underlying philosophy and the consequences the over-emphasis on science is going to bring forth.

These developments along with over-institutionalization of human polity, with its rules and regulations, atomization and individualization of society has not left much room for free play of human feelings and emotions, on the one hand, and values of sympathy, compassion, kindness tolerance, generosity and forgiveness, on the other. Covetousness and greed have replaced contentment. Will this trend continue or is there a possibility of change?

This brings in the point with which we started—when *Sci. Tech.* development reaches a high point in a society, social forces emerge and assert themselves to bring humans to centre stage by allowing personal experiences, feelings and emotions to have a free play, to bring back human values to their assigned role in society. It happened in earlier societies and cultures. Will it happen now?

There are some indications in that direction. Some critical thinkers and some groups on the fringes are already pointing in this direction.

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